REVISIONS AND CORRECTIONS

AREA Proceedings, Volume 41 (1940)

Changes in the text for the correction of typographical errors, and to take account of revisions, deletions and additions requested by committees in presenting their reports.

For revisions of matter submitted for adoption, see "Discussions."

Page 83, in table at bottom of page, correct heading of left-hand column is "Miles", not "Miles per Hour."

Page 109, in Section (b), second paragraph, in next to last line change "rows" to "tows."

Page 129, in first paragraph, last line, change "January 30" to "June 30."

Page 159, second paragraph under Appendix J, change sixth line to read "Experience has demonstrated that comfortable riding in passenger equipment traveling at 100 miles per hour can be provided on tangent track."

Page 193, correct the formula under 22 (h) to read: $d = \frac{270{,}000t}{s}\sqrt[3]{\frac{st}{h}}$

Page 200, in the table, weight of cast iron per cubic foot should be "0.26", not "26."

Page 244, sixth line, second paragraph, insert "or half circle groove" after words "V block."

Page 269, in tabulation, middle of page, change "unsatisfactory" to "satisfactory."

Page 294, change Conclusions, (2) as follows: "It provides closer day-to-day supervision over and cooperation with the foreman."

Page 381, in sixth paragraph, fifth line, delete "space."

Page 384, preceding heading "Blended Cements" revise line to read "one percent provided that such materials have been shown not to be harmful by its Committee C–1 on Cement."

Page 391, change last sentence under "Chemical Tests" to read: "In the Standard Specifications for Portland Cement there are and have been for many years past, limits placed upon the following chemical compounds."

Page 446, under "212. Plastic Cement," change fifteenth line to read "heated in an oven at 221 to 230 degrees F. (105 to 110 degrees C.)"

Page 521, numerator of second expression in the equation should read *"CM"* instead of *"C."*

Page 522, correct equation, eighth line, to read: $a = C \times 25.3\sqrt{\frac{A}{640}}$

Page 525, second line, add parentheses to $(1.0\ N)^1$. Under "8. Calculation", change formula to read: "Percentage acid-soluble matter $= \frac{\text{Wt. of residue in grams} \times 100}{\text{Wt. of dry specimen in grams}}$

Page 560, Appendix D, first line under personnel, change "Railway" to "Roadway."

Page 565, change fifth paragraph to read: "The use of twin tie plates makes for economy, due to their design being such that a very few kinds cover the requirements for a great many locations. They are, therefore, shown on several of the redrawn switch plans."

Page 605, delete all but first expression for "δ", delete all but last expression for "Δ".

Page 647, change end of second paragraph to read: "Tidewater Virginia."

PROCEEDINGS

OF THE

FORTY-FIRST ANNUAL CONVENTION

OF THE

American Railway Engineering Association

HELD AT THE

PALMER HOUSE, CHICAGO, ILLINOIS
March 12, 13 and 14, 1940

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CHICAGO

A

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* Died March 20, 1940.

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CONSTITUTION

Revised to June 7, 1940

Article I

Name, Object and Location

1. Name

The name of this Association shall be the AMERICAN RAILWAY ENGINEERING ASSOCIATION.

2. Object

The object of the Association shall be the advancement of knowledge pertaining to the scientific and economic location, construction, operation and maintenance of railways.

3. Means to be Used

The means to be used for this purpose shall be:

(a) The investigation of matters pertaining to the object of the Association through Standing and Special Committees.

(b) Meetings for discussion of reports and papers.

(c) The publication of papers, reports and discussions.

4. Conclusions

The conclusions reached shall be recommendatory.

5. Location

The office of the Association shall be located in Chicago, Illinois.

Article II

Membership

1. Classes

The membership of this Association shall be divided into five classes: Members, Life Members, Honorary Members, Associates and Junior Members.

2. Qualifications

A. General

(a) An applicant to be eligible for membership in any class other than that of Junior Member shall be not less than twenty-five (25) years of age.

(b) To be eligible for election to or retention of membership as a Member or an Associate, a person shall not be engaged directly and primarily in the sale to railways of appliances, supplies, patents or patented services.

B. Member

A Member shall be:

(a) An Engineer or Officer in the service or on the retired list of a railway corporation who has had not less than five (5) years' of experience in the location, construction, operation or maintenance of railways.

Graduation in engineering from a school of recognized standing shall be considered as equivalent to three (3) years of active practice, and the satisfactory completion of each year of work in such school, without graduation, shall be considered as equivalent to one-half year of active practice.

(b) A Professor of Engineering in a university or college of recognized standing.

(c) An Engineer or Member of a public board or commission who in the discharge of his regular duties deals with railway problems.

(d) An Engineering Editor of a magazine which deals primarily with railway matters.

C. LIFE MEMBER

A Life Member shall be a Member who has paid dues for thirty-five (35) years, or who has been retired under a recognized retirement practice and has paid dues for not less than twenty-five (25) years.

D. HONORARY MEMBER

(a) An Honorary Member shall be a person of acknowledged eminence in railway engineering or management.

(b) The number of Honorary Members shall be limited to ten (10).

E. ASSOCIATE

An Associate shall be:

(a) An Engineer of a railway which is essentially an adjunct of an industry or which is used primarily to transport the products and materials of an industry to and from a railway which is a common carrier.

(b) A person qualified by training and experience to co-operate with Members in the object of this Association but who is not qualified to become a Member.

F. JUNIOR MEMBER

(a) A Junior Member shall be not less than twenty-one (21) years of age and shall be an engineering employee of a railway corporation who has had not less than three (3) years of experience in the location, construction, operation or maintenance of railways.

Graduation in engineering from a school of recognized standing shall be considered as equivalent to three (3) years of active practice, and the satisfactory completion of each year of work in such school without graduation, shall be considered as equivalent to one-half year of active practice.

(b) His membership in this Association shall terminate at the end of the calendar year in which he becomes thirty (30) years of age.

(c) He may make application for membership other than as a Junior Member at any time when he becomes eligible to do so.

3. Transfers

The Board of Direction shall transfer from one class of membership to another, or may remove from membership any person whose qualifications so change as to warrant such action.

4. Rights

(a) Members and Life Members shall have all the rights and privileges of the Association.

(b) Honorary Members shall have all the rights and privileges of the Association except those of holding elective office, provided, however, that Members or Life Members who are elected Honorary Members shall retain all the rights and privileges of the Association.

(c) Associates and Junior Members shall have all the rights and privileges of the Association, except those of voting and holding elective office.

Article III

ADMISSION, RESIGNATION, EXPULSION AND REINSTATEMENT

1. Charter Membership

The Charter Membership of this Association consists of all persons elected to membership before March 15th, 1900.

2. Application for Membership

(a) A person desirous of membership in this Association shall make application upon the form provided by the Board of Direction. In the event that Junior Membership is desired, the application shall so state.

(b) The applicant shall give the names of at least three Members of this Association to whom personally known. Each of such Members shall be requested by the Secretary of the Association to certify to a personal knowledge of the applicant with an opinion of the applicant's fitness or otherwise for membership.

(c) If an applicant is not personally known to three Members of this Association, the names of at least three well known persons engaged in railway or allied professional work to whom personally known shall be given instead. Each of such persons shall be requested by the Secretary of the Association to certify to a personal knowledge of the applicant with an opinion of the applicant's fitness or otherwise for membership.

(d) No further action shall be taken upon the application until replies have been received from at least three of the persons named by the applicant as references.

3. Election to Membership

(a) Upon completion of the application in accordance with Section 2 of this Article the Board of Direction through its Membership Committee shall consider the application and make such investigation as it may consider desirable or necessary.

(b) Upon completion of such consideration and investigation, each member of the Board of Direction shall be supplied with all the information obtained, together with the recommendation of the Membership Committee as to the class of membership, if any, to which the applicant is eligible and the admission of the applicant shall be canvassed by letter ballot among the members of the Board of Direction.

(c) In the event that an application has been made under the provisions of Section 2, Paragraphs (a) and (b) of this Article, a two-thirds affirmative vote of the entire Board of Direction shall be required for election.

(d) In the event that an application has been made under the provisions of Section 2, Paragraphs (a) and (c) of this Article, a unanimous affirmative vote of the entire Board of Direction shall be required for election.

4. Subscription to the Constitution

A person elected to membership in this Association shall subscribe to its Constitution on the form prescribed by the Board of Direction. If this provision has not been complied with within six months of notice of election the election shall be considered null and void.

5. Honorary Member

A proposal for Honorary Membership shall be endorsed by ten or more Members of the Association and a copy furnished each member of the Board of Direction. The nominee shall be declared an Honorary Member upon receiving a unanimous vote of the entire Board of Direction.

6. Resignation

The Board of Direction shall accept the resignation, tendered in writing, of any person holding membership in the Association whose obligations to the Association have been fully met.

7. Expulsion

Charges may be preferred in writing by ten or more Members against a person holding membership in the Association. The person complained of shall be served with a copy of such charges and shall be given an opportunity to answer them to the Board of Direction. After such opportunity has been given, the Board of Direction shall take final action. A two-thirds affirmative vote of the entire Board of Direction shall be required for expulsion.

8. Reinstatement

(a) A person having been a Member, an Associate or a Junior Member of this Association and having resigned such membership while in good standing may be reinstated by a two-thirds affirmative vote of the entire Board of Direction.

(b) A person having been a Member, an Associate or a Junior Member of this Association and having forfeited membership under the provisions of Article IV, Section 3, may, upon such conditions as may be fixed by the Board, be reinstated by a two-thirds affirmative vote of the entire Board of Direction.

ARTICLE IV

DUES

1. Entrance Fee

(a) An entrance fee of ten dollars ($10.00) shall be payable to the Association with each application for membership other than Junior Membership. This sum shall be returned to an applicant not elected.

(b) No entrance fee shall be payable to the Association on account of Junior Membership.

2. Annual Dues

(a) The annual dues for each Member and each Associate shall be ten dollars ($10.00).

(b) The annual dues for each Junior Member shall be five dollars ($5.00).

(c) Life Members and Honorary Members shall be exempt from the payment of dues.

3. Arrears

A person whose dues are not paid before April 1st of the current year shall be notified by the Secretary. If the dues are still unpaid on July 1st further notice shall be given and a delinquent Member shall lose the right to vote. If the dues remain unpaid October 1st the person shall be notified on the form prescribed by the Board of Direction, and shall no longer receive the publications of the Association. If the dues are not paid by December 31st, the person shall forfeit membership without further action or notice, except as provided for in Section 4 of this Article.

4. Remission of Dues

The Board of Direction may extend the time of payment of dues, and may remit the dues of any Member, Associate or Junior Member who, for good reason, is unable to pay them.

Article V

OFFICERS

1. Officers

(a) The officers of the Association shall be a President, two Vice-Presidents, nine Directors, a Secretary and a Treasurer.

(b) The President, the Vice-Presidents and the Directors, together with the five latest living Past-Presidents continuing to be Members, shall constitute the Board of Direction, in which the government of the Association shall be vested, and shall act as Trustees and have the custody of all property belonging to the Association. The President, the Vice-Presidents and the Directors shall be Members.

(c) The Secretary and the Treasurer shall be appointed by the Board of Direction.

2. Term of Office

The term of office of the President shall be one year, of the Vice-Presidents two years and of the Directors three years. The term of each shall begin at the close of the Annual Convention at which elected and continue until a successor is qualified. All other officers and employees shall hold office or position during the pleasure of the Board of Direction.

3. Officers Elected Annually

(a) There shall be elected at each Annual Convention a President, one Vice-President and three Directors.

(b) The candidates for President and for Vice-President shall be selected from the members or past members of the Board of Direction.

4. Conditions of Re-election of Officers

A President shall be ineligible for re-election. Vice-Presidents and Directors shall not be eligible for re-election to the same office until at least one full term has elapsed after the end of their respective terms.

5. Vacancies in Offices

(a) When a vacancy occurs in the office of President the duties shall be performed by the senior Vice-President.

(b) When a vacancy occurs in the office of either Vice-President the Board of Direction shall select a Vice-President from among the Directors. A Vice-Presidency shall not be considered vacant when one of the Vice-Presidents is filling a vacancy in the Presidency.

(c) A vacancy in the office of Director shall be filled by the Board of Direction.

(d) An incumbent in any office for an unexpired term shall be eligible for re-election to the office held; provided however, that anyone appointed to fill a vacancy as Director within six months after the term commences shall be considered as coming within the provisions of Article V, Section 4.

6. Vacation of Office

(a) When an elected officer ceases to be a Member of the Association, as provided in Article II, the office shall be vacated.

(b) In case of the disability of or neglect in the performance of duty by an officer, the Board of Direction, by a two-thirds affirmative vote of the entire Board, shall have the power to declare the office vacant.

Article VI

NOMINATION AND ELECTION OF OFFICERS

1. Nominating Committee

(a) There shall be a Nominating Committee composed of the five latest living Past-Presidents of the Association, who are Members, and five Members who are not officers.

(b) The five Members who are not officers shall be elected annually for a term of one year, when the officers of the Association are elected.

(c) The senior Past-President who is a member of the Committee shall be the Chairman of the Committee. In the absence of the senior Past-President from a meeting of the Committee the Past-President next in seniority present shall act as Chairman.

2. Method of Nominating

(a) Prior to December 1st of each year the Chairman shall call a meeting of the Committee at a convenient place, at which nominees for the various elective offices shall be selected as follows:

Office to be Filled	*Number of Candidates to be named by the Nominating Committee.*	*Number of Candidates to be elected at the Annual Election of Officers.*
President	1	1
Vice-President	1	1
Directors	9	3
Nominating Committee	10	5

(b) The Chairman of the Nominating Committee shall send the names of the nominees to the President and Secretary not later than December 15th of the same year, and the Secretary shall report them to the members of the Association on a printed slip not later than January 1st following.

(c) At any time between January 1st and February 1st any ten or more Members may send to the Secretary additional nominations for any elective office for the ensuing year signed by such Members.

(d) If any person nominated shall be found by the Board of Direction to be ineligible for the office for which nominated, or should a nominee decline such nomination, the name shall be withdrawn. The Board of Direction may fill any vacancies that may occur in the list of nominees up to the time the ballots are sent out.

3. Ballots Issued

Not less than thirty days prior to each Annual Convention, the Secretary shall issue a ballot to each voting member of record in good standing, listing the several candidates to be voted upon. When there is more than one candidate for any office, the names shall be arranged on the ballot in the order that shall be determined by lot by the Nominating Committee. The ballot shall be accompanied by a statement giving for each candidate, his record of membership and activities in this Association.

4. Substitution of Names

Members may erase names from the printed ballot list and may substitute the name or names of any other person or persons eligible for any office, but the number of names voted for each office on the ballot must not exceed the number to be elected at that time to such office.

5. Ballots

(a) Ballots shall be placed in an envelope, sealed and endorsed with the name of the voter, and mailed to or deposited with the Secretary at any time previous to the closure of the polls.

(b) A voter may withdraw a ballot, and cast another, at any time before the polls close.

(c) Ballots not endorsed or from persons not qualified to vote shall not be counted.

(d) The ballots and envelopes shall be preserved for not less than ten days after the vote is canvassed.

6. Closure of Polls

The polls shall be closed at twelve o'clock noon on the second day of the Annual Convention, and the ballots shall be counted by tellers appointed by the Presiding Officer.

7. Election

(a) The persons who shall receive the highest number of votes for the offices for which they are candidates shall be declared elected.

(b) In case of a tie between two or more candidates for the same office, the Members present at the Annual Convention shall elect the officer by ballot from the candidates so tied.

(c) The Presiding Officer shall announce at the convention the names of the officers elected in accordance with this Article.

Article VII

MANAGEMENT

1. President

The President shall have general supervision of the affairs of the Association, shall preside at meetings of the Association and of the Board of Direction, and shall be ex-officio a member of all committees, except the Nominating Committee.

2. Vice-Presidents

The Vice-Presidents, in order of seniority, shall preside at meetings in the absence of the President and shall discharge the duties in case of a vacancy in the office.

3. Treasurer

The Treasurer shall receive all monies, deposit the same in the name of the Association, receipt to the Secretary therefor and invest all funds not needed for current disbursements as shall be ordered by the Board of Direction. The Treasurer shall pay all bills, when properly certified and audited by the Finance Committee, and make such reports as may be called for by the Board of Direction.

4. Secretary

The Secretary, shall be under the direction of the President and Board of Direction, the Executive Officer of the Association and shall attend the meetings of the Association and of the Board of Direction, prepare the business therefor, and duly record the proceedings thereof. The Secretary shall see that the monies due the Association are collected and without loss transferred to the custody of the Treasurer, and shall personally certify to the accuracy of all bills or vouchers on which money is to be paid. The Secretary is to conduct the correspondence of the Association, keep proper record thereof, and perform such other duties as the Board of Direction may prescribe.

5. Auditing of Accounts

The accounts of the Treasurer and of the Secretary shall be audited annually by an approved accountant under the direction of the Finance Committee of the Board of Direction.

6. Board of Direction

(a) The Board of Direction shall manage the affairs of the Association, and shall have full power to control and regulate all matters not otherwise provided in the Constitution.

(b) The Board of Direction shall meet within thirty days after each Annual Convention, and at such other times as the President may direct. Special meetings shall be called on request, in writing, of five members of the Board of Direction.

(c) Seven members of the Board of Direction shall constitute a quorum.

(d) At the first meeting of the Board of Direction after the Annual Convention, the following committees, each consisting of not less than three members, shall be appointed by the President from the Board of Direction and they shall report to and perform their duties under the supervision of the Board of Direction.

Finance
Publication
Outline of Work of Committees
Personnel of Committees
Membership
Manual

7. Duties of the Committees of the Board of Direction

(a) Finance Committee

The Finance Committee shall have immediate supervision of the accounts and financial affairs of the Association; shall approve all bills before payment, and shall make recommendations to the Board of Direction as to the investment of monies and other financial matters. The Finance Committee shall not have the power to incur debts or other obligations binding the Association, nor authorize the payment of money other than the amounts necessary to meet ordinary current expenses of the Association, except by authority of the Board of Direction.

(b) Publication Committee

The Publication Committee shall have general supervision of the publications of the Association. The Publication Committee shall not have the power to incur debts or other obligations binding the Association, nor authorize the payment of money except by authority of the Board of Direction.

(c) Committee on Outline of Work of Committees

The Committee on Outline of Work of Committees shall prepare and present to the Board of Direction a report of the subjects to be investigated, considered and reported upon by the standing and special committees of the Association during the ensuing year.

(d) Committee on Personnel of Committees

The Committee on Personnel of Committees shall prepare and present to the Board of Direction a list of chairman, vice-chairmen and members of the standing and special committees of the Association for the ensuing year.

(e) Membership Committee

The Membership Committee shall make investigation of applicants for membership and shall make recommendations to the Board of Direction with reference thereto.

(f) Manual Committee

The Manual Committee shall study and recommend to the Board of Direction as to the manner in which the material adopted for addition or deletion from the Manual shall be handled.

8. Standing Committees

The Board of Direction may appoint standing committees to investigate, consider and report upon questions pertaining to railway location, construction, operation and maintenance.

9. Special Committees

The Board of Direction may appoint special committees to examine into and report upon any subject connected with the objects of this Association.

10. Discussion by Non-Members

The Board of Direction may invite discussions of reports from persons not members of the Association.

11. Sanction of Act of Board of Direction

An act of the Board of Direction which shall have received the expressed or implied sanction of the membership at the next annual convention of the Association shall be deemed to be the act of the Association.

Article VIII

MEETINGS

1. Annual Convention

(a) The Annual Convention of the Association shall be held in the City of Chicago, Illinois. The convention shall open on a Tuesday in the month of March to be determined by the President.

(b) The Secretary shall notify all members of the Association of the time and place of the Annual Convention at least thirty (30) days in advance thereof.

(c) The order of business at the Annual Convention of the Association shall be:

Reading of the Minutes of the last meeting
Address of the President
Reports of the Secretary and the Treasurer
Reports of Committees
Unfinished Business
New Business
Installation of Officers
Adjournment

(d) This order of business may be changed by a majority vote of Members present.

(e) The proceedings shall be governed by "Robert's Rules of Order" except as otherwise herein provided.

(f) Discussions shall be limited to members and to those others invited by the Presiding Officer to speak.

2. Special Meetings

Special meetings of the Association may be called by the Board of Direction and special meetings shall be so called by the Board of Direction upon written request of thirty Members. The request shall state the purpose of such meeting.

The call for such special meeting shall be issued not less than ten (10) days in advance and shall state the purpose and place of the meeting. No other business shall be taken up at such meeting.

3. Quorum

Twenty-five (25) Members shall constitute a quorum at all meetings of the Association.

Article IX

AMENDMENT

1. Amendment

Proposed Amendment of this Constitution shall be made in writing, shall be signed by not less than ten Members and shall be acted upon in the following manner:

The amendment shall be presented to the Secretary, who shall send a copy to each member of the Board of Direction as soon as received. If a majority of the entire Board of Direction so votes the matter shall be submitted to the Association by letter-ballot.

The Board of Direction shall canvass the ballots which have been received within sixty days after the date of issue of the letter-ballot and if two-thirds (⅔) of the votes so received are in the affirmative the amendment shall be declared adopted and shall become immediately effective.

The result shall be announced at the next Annual Convention.

GENERAL INFORMATION

(Subject to change from time to time by Board of Direction)

GENERAL RULES FOR THE PREPARATION, PUBLICATION AND CONSIDERATION OF COMMITTEE REPORTS

(A) Appointment of Committees and Outline of Work

Standing Committees

1. The following are Standing Committees:

1. Roadway and Ballast.
3. Ties.
4. Rail.
5. Track.
6. Buildings.
7. Wood Bridges and Trestles.
8. Masonry.
9. Highways.
10. Signals and Interlocking.
11. Records and Accounts.
12. Rules and Organization.
13. Water Service, Fire Protection and Sanitation.
14. Yards and Terminals.
15. Iron and Steel Structures.
16. Economics of Railway Location and Operation.
17. Wood Preservation.
18. Electricity.
20. Uniform General Contract Forms.
22. Economics of Railway Labor.
24. Cooperative Relations with Universities.
25. Waterways and Harbors.
26. Standardization.
27. Maintenance of Way Work Equipment.

Special Committees

2. Special Committees will be appointed from time to time, as may be deemed expedient, in the manner prescribed by Article VII, Section 9, of the Constitution.

The following are Special Committees:

Stresses in Railroad Track.
Clearances.
Waterproofing of Railway Structures.
Impact.

Personnel of Committees

3. The personnel of all committees will continue from year to year, except when changes are announced by the Board of Direction. It is desirable that ten percent of the membership of each committee be changed each year.

Members of committees who do not attend meetings of committees during the year or render service by correspondence will be relieved and the vacancies filled by the Board at the succeeding annual convention.

Outline of Work

4. As soon as practicable after the reports of committees for the current year have been filed with the secretary, the Board of Direction will assign to the committees, subjects which in its judgment should preferably be considered during the succeeding year, provided, however, that such assignments may be subject to revision until the close of the Annual Convention. *Such assignments should not be deviated from except in extreme cases and then not until approved by the Committee on Outline of Work.*

(B) Preparation of Committee Reports

General

5. The objectives of the Association are advanced through the work of the committees in two ways—(1) the development of useful information pertinent to their assignments to be presented to the Association "as information", and (2) the formulation of recommended practices to be submitted for adoption and publication in the Manual.

(a) Whether the report on any particular assignment should take the form of "information" or a "recommended practice", depends largely on the nature of the assignment. Some assignments will be fulfilled completely by the presentation of information; others call for information in support of appended recommendations that are submitted for adoption. In still other cases, the primary objective is a comprehensive statement of recommended practices, but the development of these recommended practices may entail investigation or research work, the results of which are of such importance as to warrant their presentation as information prior to the submission of the recommendations. In some cases, also, it may be advisable to submit as information matter in the form of recommended practice, with a view to inviting suggestions and criticisms that may serve as the basis for revisions prior to the resubmission of the matter for adoption a year later.

Planning the Work

6. In pursuing the work on any assignment, the first step is necessarily one of fact finding, including (a) a study of available literature on the subject, particularly reports of previous investigations, (b) a compilation of current practice, especially recent changes in practice, and (c) resort to original tests or experimentation, after a canvass of all other sources of information indicates that research work is necessary.

Collection of Data

(a) Committees are privileged to obtain data or information in any proper way. If desired, the secretary will issue circulars of inquiry, which should be brief and concise. The questions asked should be specific and pertinent, and not of such general or involved character as to preclude the possibility of obtaining satisfactory and prompt responses. They should specify to whom answers are to be sent, and should be in such form that copies can be retained by persons replying either by typewriter or blueprint.

(b) Requests for appropriations for the conduct of research work should be sent to the secretary with a supporting statement setting forth: (a) the nature of the information sought; (b) how the railroads are adversely affected by the lack of this information; (c) the estimated cost of the investigation; (d) the estimated time to complete the work; (e) the basis for assuming that the investigation will produce the data desired; and, (f) an estimate of the savings to be realized or other advantages to accrue from the successful completion of the investigations. A request for funds to continue or complete an investigation shall include a statement of the results obtained to date.

Reports

7. Committees should pursue their investigations on all assignments but are expected to present progress or final reports for publication only on those assignments regarding which pertinent information has been developed.

(a) Committees are privileged to present the results of any special study or investigation they may be engaged upon in connection with their assignments that may be considered of sufficient importance to warrant presentation.

(b) Reports of information, supplementing previous reports of progress, may include a brief review of matter previously presented, but should avoid extended repetition of such matter.

(c) Matter offered for adoption and publication in the Manual should be submitted in full, regardless of its publication in previous years.

(d) Illustrations accompanying reports should, when possible, be prepared so that they can be reproduced on one page. The use of inserts should be avoided.

(e) One of the most important duties of each committee is to examine its own subject-matter in the Manual each year and submit such revisions of or supplements to the Manual as are deemed necessary to keep it up to date. New matter for publication in the Manual and revisions thereof must be submitted in the form and manner specified in the General Rules for Publication of the Manual.

Form of Reports

8. Committee reports shall be prepared in accordance with the Instructions published in the annual pamphlet of committee assignments and personnel.

(C) PUBLICATION OF REPORTS

Dates for Filing and Publication of Reports

9. For the convenience of those attending the convention, the reports of committees to be presented at any session of the annual convention will be published, so far as possible, in the same bulletin. To carry out this plan requires a careful scheduling of the filing of reports and the publication of bulletins, and the arrangement of the convention program. It is of utmost importance that chairmen file complete reports of their committees on or before the dates specified on the schedule furnished them.

Written Discussions

10. Written discussions of published reports will be transmitted to the chairman of the interested committee who will read or present them by title or in abstract at the convention. Written discussions will be published in the Proceedings as a part of the discussion of the committee reports.

Verbal Discussions

11. Each speaker's remarks will be submitted to him in writing before publication in the Proceedings, for the correction of diction and errors of reporting, but not for the elimination of remarks.

(D) CONSIDERATION OF COMMITTEE REPORTS

Sequence

12. The sequence in which committee reports will be considered by the convention will be determined by the Board of Direction.

Method

13. Reports offered as information will be presented by title or by a brief outline of the contents. Comments or criticisms may be offered from the floor upon invitation from the presiding officer.

14. Matter submitted for adoption and publication in the Manual may receive consideration by one of the following procedures:

(a) Reading by title.
(b) Reading, discussing and acting upon each conclusion separately.
(c) By majority vote, discussion will be had on each item. Clauses not objected to when read will be considered as voted upon and adopted.

Action on Reports

15. No formal action is to be taken by the convention on matter submitted as information, whether in the form of a progress or final report.

Action on matter submitted for adoption and publication in the Manual will be one of the following:

(a) Adoption as a whole as presented.
(b) Affirmative action on the amendment of a part or parts of the matter presented, followed by adoption as a whole, as amended.
(c) Adoption of a part, complete in itself, and referring of remainder back to the committee.
(d) Recommittal with or without instructions.

NOTE.—An amendment which affects underlying principles, if adopted, shall of itself constitute a recommittal of such part of the report as the committee considers affected.

The Chair will decline to entertain amendments which in his opinion are primarily a matter of editing.

(E) PUBLICATION OF ABSTRACTS BY TECHNICAL JOURNALS

The following rules will govern the releasing of matter for publication in technical journals:

Committee reports, requiring action by the Association at the annual convention, will not be released until after presentation to the convention; special articles, contributed by members and others, on which no action by the Association is necessary, are to be released for publication by the technical journals after issuance in the bulletin; provided, application therefor is made in writing and proper credit be given the Association, authors or committees presenting such material.

GENERAL RULES FOR PUBLICATION OF THE MANUAL

Title

1. The title of the volume will be "Manual of the American Railway Engineering Association."

2. The Board of Direction shall have the authority to withhold from publication any matter which it shall consider as not desirable to publish, or as not being in proper shape, or as not having received proper study and consideration.

Contents

3. The matter adopted by the Association for publication in the Manual shall be considered Recommended Practice, but shall not be binding on the members. Recommended Practice, as defined by the Board of Direction (May 20, 1936) is a material, device, plan, specification or practice recommended to the railways for use as required, either exactly as presented or with such modifications as may be necessary or desirable to meet the needs of individual railways, but in either event, with a view to promoting efficiency or economy, or both, in the location, construction, operation or maintenance of railways.

Requisites for Adoption

4. The Manual will include only such matter as has been made the subject of a special study by a standing or special committee and embodied in a committee report, published not less than thirty days prior to the Annual Convention, and submitted by the committee to the Annual Convention, and which, after due consideration and dis-

cussion, shall have been voted on and formally adopted by the Association. Subjects which, in the opinion of the Board of Direction shall be reviewed by the Association of American Railroads, may be referred to that association before being published in the Manual.

5. All conclusions included in the Manual must be in concise and proper shape for publication, as the Manual will consist only of a summary record of the definitions, specifications and principles of practice adopted by the Association, with a brief reference to the published Proceedings of the Association for the context of the committee report and subsequent discussion and the final action of the Association.

Revision

6. Any matter published in the Manual may be amended or withdrawn by vote at any subsequent Annual Convention, provided such changes are proposed in time for publication not less than thirty days prior to the Annual Convention, and in the following manner: (a) upon recommendation of the committee in charge of the subject; (b) upon recommendation of the Board of Direction; (c) upon request of five members, made to the Board of Direction.

7. Revisions of or additions to the Manual authorized by action at each convention will be published annually in the form of loose-leaf sheets which will be made available to all holders of the Manual. These supplemental sheets will be accompanied by instructions for insertion of the new sheets and the withdrawal of sheets that have been superseded, as well as those that have been withdrawn by action of the Association.

Report of Committee 26—Standardization

F. L. Nicholson, *Chairman,*
J. R. W. Ambrose
John E. Armstrong
W. G. Arn
Hadley Baldwin
F. L. C. Bond
A. E. Botts
J. G. Brennan
H. F. Brown
H. M. Church
B. W. DeGeer
W. T. Dorrance
John Foley
C. F. Ford
J. B. Hunley
C. A. Knowles
L. H. Laffoley
J. A. Lahmer
J. F. Leonard
H. G. Morgan
John V. Neubert
W. G. Nusz
G. M. O'Rourke
G. P. Palmer
H. M. Stout
Dr. A. N. Talbot
R. A. Van Ness
G. R. Westcott
A. R. Wilson
Committee.

To the American Railway Engineering Association:

Your committee respectfully reports on the following assignments:

1. What AREA recommended practices should be advocated for general use on railroads. Your committee has reviewed the Manual and submits a tabulation of recommended practices thought worthy of general use by the railroads in the interest of uniformity in practice, economy and efficiency (Appendix A). A similar tabulation was submitted in 1937, but it is thought desirable again to bring the matter to your attention. Your committee earnestly recommends that, in so far as possible, the recommended practices be adopted by the railroads represented in this Association.

2. What AREA recommended practices should be sponsored as subjects for National Standardization. The committee presents no recommendations at this time.

3. Maintain contact with standardization bodies and keep the Association informed on important matters developed by such contact. Your committee presents herewith (a) A list of representatives of the Association of American Railroads on the council of the American Standards Association and on its Correlating and Advisory Committee; (b) A list of technical projects on which the AAR is now co-operating with the ASA, together with the names of members representing the AAR in the consideration of such projects. The information was furnished by Mr. P. G. Agnew, secretary of the American Standards Association (Appendix B).

A summary of the activities of the Canadian Engineering Standards Association for the year ending March 31, 1939. This information was furnished by Mr. W. R. McCaffrey, secretary of CESA (Appendix C).

A list of collaborating representatives of the AREA on committees of the American Society for Testing Materials (Appendix D).

This report is submitted as information.

The Committee on Standardization,
F. L. Nicholson, *Chairman.*

Appendix A

Tabulation of Specifications and Recommended Practices as Contained in the Manual, Presented for Uniform Practice on All Railroads

The following items have been selected from the material adopted by the Association as recommended practices and printed in the Manual; as worthy of adoption on all railroads in the interest of economy and efficiency. The list is set up in subdivisions conforming to standing committee numbers. A similar list was presented in 1937 and it is now thought wise to bring this matter to your attention again.

Bulletin 413, November, 1939.

I—Roadway

Item	*Manual Reference*
Specifications for Cast Iron Pipe Culverts	1– 12 (ASTM A
Specifications for Corrugated Metal Culverts	1– 13 142–34T)
Specifications for Pipe Line Crossings Under Railway Tracks	1– 25
Specifications for the Formation of the Roadway	1– 27
Specifications for Concrete Fence Posts	1– 67
Specifications for Metal Fence Posts	1– 71
Specifications for Standard Right-of-Way Fences	1– 73
Specifications for Construction, Excavation and Temporary Lining of Tunnels	1– 66.1

2—Ballast

Specifications for Stone Ballast	2– 1
Specifications for Prepared Gravel Ballast	2– 7
Specifications for Prepared Blast Furnace Slag Ballast	2– 13

3—Ties

Specifications for Crossties	3– 1
Specifications for Switch-Ties	3– 11
Methods and Practices for Proper Seasoning of Ties, etc.	3– 16
Specifications for Tie Plugs	3– 21
Specifications for Dating Nails	3– 23
Anti-Splitting Devices	3– 25

4—Rail

Standard Specifications for Open-Hearth Steel Rails	4 –1
Standard Rail Sections, 90-lb., 100-lb., 112-lb. and 131-lb.	4 –7
Drilling of Rails	4 –12
Standard Locations for Tension Test Specimens and for Boring for Chemical Analyses	4 –13
Recommended Practice for Rail Inspection	4 –13
Specifications for High-Carbon-Steel Joint Bars	4 –17
Specifications for Quenched Carbon-Steel Joint Bars	4 –21
Joint Bars and Assemblies for 90-lb., 100-lb., 112-lb. and 131-lb. Rail	4– 24
Specifications for Heat-Treated Carbon-Steel and Alloy-Steel Track Bolts	4– 29
Design for Track Bolts	4– 33
Specifications for Spring Washers	4– 37
Specifications for Open-Hearth Steel Girder Rails of Plain, Grooved and Guard Types	4– 57
Girder Rail Sections	4– 63
Joint Bars for 128-lb. and 159-lb. Girder Rail	4– 68

5—Track

AREA Portfolio of Trackwork Plans	
Specifications for Steel Tie Plates	5– 1
Design of Tie Plate for RE Rail Sections	5– 5
Specifications for Wrought Iron Tie Plates	5– 11
Specifications for Soft Steel Cut Track Spikes	5– 15
Design of Cut Track Spike	5– 17
Specifications and Plans for Track Tools	5– 47

6—Buildings

Specifications for Buildings for Railway Purposes	6– 1

7—Wood Bridges and Trestles

Item	*Manual Reference*
Specifications for Wood Piles	7– 1
Specifications for Workmanship for Pile and Framed Trestles of Untreated Material to be Built Under Contract	7– 7
Specifications for Wood Shingles	7– 11
Specifications for Structural Timbers	7– 17
Grading Rules and Classification of Timber and Lumber for Railway Uses	7– 69

8—Masonry

Specifications for Portland Cement Concrete, Plain and Reinforced	8– 1
Specifications for Rigid Frame Concrete Bridges	8– 73.1
Specifications for Making Pre-Molded Concrete Piles	8– 87
Specifications for Driving Pre-Molded Concrete Piles	8– 89
Specifications for Reinforced Concrete Culvert Pipe	8– 90
General Specifications for Substructures of Railway Structures	8– 91
Specifications for Shotcrete	8– 95
Specifications for Repairing Deteriorating Concrete	8– 99
Specifications for Lining Railway Tunnels with Plain Concrete	8–103
Specifications for Stone Masonry	8–109

9—Highways

Specifications for Preparation of Track Structure, Width of Crossing and Approaches for Construction of Street Crossings Over Railway Track	9– 3
Specifications for the Construction of Bituminous Crossings	9– 5
Specifications for the Construction of Rail Type Street Crossings	9– 9
Highway Crossing Signs and Signals	9– 17 (Bulletin No. 2 AAR)

13—Water Service, Fire Protection and Sanitation

Specifications for Cast Iron Pipe and Special Castings	13– 15
Specifications for Wood Water Tank	13– 21
Specifications for Steel Water and Oil Tanks	13– 37
Specifications for Soda Ash to be Used in Water Treatment	13– 43
Specifications for Hydrated Lime to be Used in Water Treatment	13– 45
Specifications for Quicklime to be Used in Water Treatment	13– 47
Specifications for Sulphate of Alumina to be Used in Water Treatment	13– 49
Specifications for Sulphate of Iron to be Used in Water Treatment	13– 51
Specifications for Salt to be Used in Regeneration of Zeolite Water Softening Plants	13– 55

14—Yards and Terminals

Rules for the Location, Maintenance, Operation and Testing of Railway Track Scales	14– 33
Specifications for the Manufacture and Installation of 4-Section, Knife-Edge Railway Track Scales	14– 47
Specifications for the Manufacture and Installation of 2-Section, Knife-Edge Railway Track Scales	14– 67
Specifications for the Manufacture and Installation of Motor Truck, Built-In, Self-Contained and Portable Scales for Railway Service	14– 85
Large-Capacity Scales—Tolerances, SR Requirements, and Regulations	14–107

15—Iron and Steel Structures

Item	*Manual Reference*
Specifications for Steel Railway Bridges	15– 1
Specifications for Movable Railway Bridges	15– 49
Requirements for the Protection of Traffic at Movable Bridges	15– 93
Specifications for Steel Railway Turntables	15–109
Instructions for the Mill Inspection of Structural Steel	15–115
Instructions for the Inspection of the Fabrication of Steel Bridges	15–116
Instructions for the Inspection of Bridge Erection	15–118
Classification of Railway Bridges	15–119
Rules for Rating Existing Iron and Steel Bridges	15–121

17—Wood Preservation

Specifications for Treating Processes	17– 5
Specifications for Preservatives	17– 13
Specifications for Treatment of Douglas Fir	17– 47
Specifications for Treatment of Air-Seasoned Douglas Fir	17– 57

20—Uniform General Contract Forms

Form of Construction Contract	20– 1
Form of Cost-Plus Percentage Construction Contract	20– 11
Forms of Agreement For:	
Organization and Operation of a Joint Passenger Terminal Project	20– 21
Joint Use of Passenger Station Facilities	20– 47
Joint Use of Freight Terminal Facilities	20– 53
Interlocking Plant	20– 61
Trackage Rights	20– 67
Industry Track	20– 73
Crossing of Railways at Grade	20– 81
Purchase of Electrical Energy for Traction and Other Purposes	20– 91
Purchase of Electrical Energy for Other Than Traction Purposes	20–101
Use of Railway Property by High Pressure Pipe Lines With Special Reference to Pipe Lines Carrying Inflammable Oils and Gas	20–105
Joint Use of Poles on Railway Lands	20–109
Pick Up and Store Door Delivery	20–124.1

27—Work Equipment

Standardization of Parts and Accessories for Railway Maintenance Motor Cars	27– 1

Clearances

Clearances	Cl– 1
Clearance Diagrams For:	
Bridges	Cl– 2
Turntables	Cl– 3
Single-Track Tunnel	Cl– 4
Double-Track Tunnel	Cl– 5
Buildings and Sheds Adjacent to Side Tracks	Cl– 6
Warehouse and Engine House Doors	Cl– 7
Platforms	Cl– 8
Equipment, Unrestricted	Cl– 9
Equipment, Unrestricted for Main Lines	Cl– 10

Waterproofing of Railway Structures

Specifications for Membrane Waterproofing	Wpfg– 1
Specifications for Bituminous Emulsions for Dampproofing	Wpfg– 17

Appendix B

Representation of the Association of American Railroads on the Standards Council of the American Standards Association 1939–1941

Principals	*Term Expires*
A. R. Wilson (Engineering Division)	Dec. 31, 1939
W. A. Jackson (Operating Division)	Dec. 31, 1940
J. E. Ennis (Mechanical Division)	Dec. 31, 1941

Alternates

K. Cartwright (Mechanical Division)
W. F. Cummings (Engineering Division)
E. M. Hastings (Engineering Division)
E. K. Post (Signal Section)
C. B. Tobey (Purchases and Stores Division)
Sidney Withington (Electrical Section)

Representation of the Association of American Railroads on Correlating and Advisory Committees of the American Standards Association

Committee	*AAR Division*	*Representatives*
Electrical Standards Committee and U. S. National Committee of the IEC	IV Eng. Electrical Sec.	Sidney Withington
Highway Traffic Standards Committee		J. G. Brennan
Mechanical Standards Committee	V Mech.	J. E. Ennis Alt. K. Cartwright
Safety Code Correlating Committee		C. E. Hill

American Standards Association Technical Projects on Which the Association of American Railroads Is Now Co-operating

	ASA Project	**AAR Divisions, Sections and committees represented*	*Representative*
A 1	Portland Cement, Specifications for	IV Eng.—Com. 8—Masonry	Meyer Hirschthal J. F. Leonard J. J. Yates
A21	Cast Iron Pipe and Fittings	IV Eng.—Com. 13—Water Service, Fire Protection and Sanitation	C. R. Knowles
A22	Walkway Surfaces, Safety Code for	IV Eng.—Com. 6—Buildings	W. T. Dorrance
A35	Manhole Frames and covers	I Oper.—T. & T. Sec.	J. A. Jones
		IV Eng.—Com. 14—Yards and Terminals	H. L. Ripley Alt. J. R. W. Ambrose
		Com. 6—Buildings	Alt. W. T. Dorrance
A36	Rating of Rivers	IV Eng.—Elec. Sec.	R. J. Needham
B 1	Screw Threads, Standardization and Unification of	IV Eng.—Com. 4—Rail	J. V. Neubert
		Sig. Sec.	H. G. Morgan
B16	Pipe Flanges and Fittings	IV Eng.—Com. 13—Water Service, Fire Protection and Sanitation	C. R. Knowles
		Elec. Sec.	vacant
		Sig. Sec.	E. K. Post
B18	Bolt, Nut and Rivet	IV Eng.—Com. 4—Rail	J. V. Neubert
		Com. 5—Track	Alt. J. B. Myers
		Com. 15—Iron and Steel Structures	Phillip G. Lang, Jr. Alt. O. E. Selby
B20	Conveyors and Conveying Machinery, Safety Code for	IV Eng.—Com. 6—Buildings	H. G. Dalton
B27	Plain and Lock Washers	IV Eng.—Com. 5—Track	E. W. Caruthers
		VI Purchases and Stores	A. G. Follette
B30	Cranes, Derricks and Hoists, Safety Code for	IV Eng.—Com. 27—M of W Work Equipment	C. L. Fero Alt. T. M. Pittman

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*AREA representation indicated by committee title or Constr. & Maint. Sec.

American Standards Association Technical Projects on Which the Association of American Railroads Is Now Co-operating—Continued

	ASA Project	**AAR Divisions, Sections and committees represented*	*Representative*
B32	Wire and Sheet Metal Gages	IV Eng.—Sig. Sec.	A. S. Haigh
B33	Hose Coupling Screw Threads	IV Eng.—Com. 13—Water Service, Fire Protection and Sanitation	W. L. Curtiss Alt. J. P. Hanley
B36	Dimensions and Materials of Wrought Iron and Wrought Steel Pipe and Tubing, Standardization of	IV Eng.—Com. 13—Water Service Fire Protection and Sanitation	J. J. Laudig
B42	Leather Belting. Specifications for	VI Purchases and Stores	C. L. McIlvaine
C 1	Electric Wiring and Apparatus in Relation to Fire Hazard, Regulations for (National Electrical Code)	IV Eng.—Elec. Sec.	G. L. Sealey
C 2	National Electrical Safety Code	IV Eng.	Sidney Withington Alt. W. R. Triem
C 5	Lightning, Code for Protection Against	I Oper.—T. & T. Sec.	J. L. Niesse
C 8	Wires and Cables, Insulated (Other than Telephone and Telegraph)	IV Eng.—Elec. Sec. Sig. Sec. V Mech.—Elec. Sec.	C. R. Troop J. J. Corcoran J. R. Sloan
C8k2	Heat Resisting Wires	IV Eng.—Elec. Sec.	J. L. Minick
C11	Hard Drawn Aluminum Conductors	IV Eng.—Elec. Sec.	K. H. Gordon
C16	Radio	I Oper.—T. & T. Sec.	J. L. Niesse
C18	Dry Cells and Batteries, Specifications for	I Oper.—T. & T. Sec. IV Eng.—Sig. Sec.	G. R. Stewart A. B. Himes
C28	Dimensions of Electric Motor Frame	V Mech.—Elec. Sec.	E. W. Barnes
C29	Insulators for Electric Power Lines	IV Eng.—Elec. Sec. Sig. Sec.	H. F. Brown G. W. Chappell
C34	Mercury Arc Rectifiers	IV Eng.—Elec. Sec.	J. S. Thorp
C35	Railway Motors and Other Rotating Electrical Machinery on Rail Cars and Locomotives	IV Eng.—Elec. Sec.	Sidney Withington
C37	Power Switchgear	IV Eng.—Elec. Sec. V Mech.—Elec. Sec.	S. R. Negley G. T. Johnson
C39	Electrical Measuring Instruments	IV Eng.—Elec. Sec.	Vacant
C42	Definitions of Electrical Terms	IV Eng.—Elec. Sec. V Mech.—Elec. Sec.	J. H. Davis E. W. Barnes
C44	Rolled Threads for Screw Shells of Electric Sockets and Lamp Bases	IV Eng.—Sig. Sec. V Mech.—Elec. Sec.	H. G. Morgan O. M. Bixby
C50	Rotating Electrical Machinery	IV Eng.—Elec. Sec.	S. Withington
C52	Electric Welding Apparatus	IV Eng.—Elec. Sec. Const. & Maint. Sec.	R. P. Winton R. P. Winton
C57	Transformers, Regulators & Reactors	IV Eng.—Elec. Sec.	S. R. Negley
C59	Electrical Insulating Materials In General	I Oper.—T. & T. Sec. IV Eng.—Sig. Sec. Elec. Sec.	W. A. Moore E. B. Smith Alt. W. F. Zane C. R. Troop
C60	Vacuum Tubes for Industrial Purposes, Standardization of	IV Eng.—Elec. Sec.	J. H. Davis
C63	Radio–Electrical Coordination	I Oper.—T. & T. Sec. IV Eng.—Elec. Sec.	J. L. Niesse J. H. Davis
E12	Loading Platforms at Freight Terminals and Warehouses	IV Eng.	A. R. Wilson Alt. W. T. Dorrance
G 8	Zinc Coating of Iron and Steel, Specifications for	I Oper.—T. & T. Sec. IV Eng.—Com. 1—Roadway Com. 13—Water Service, Fire Protection and Sanitation	J. A. Jones W. C. Pruett J. J. Laudig
H 4	Soft or Annealed Copper Wire, Specifications for	I Oper.—T. & T. Sec. IV Eng.—Elec. Sec.	J. A. Jones J. L. Minick
H14	Hard-Drawn Copper Wire, Specifications for	I Oper.—T. & T. Sec. IV Eng.—Elec. Sec.	J. A. Jones J. L. Minick
H15	Medium Hard-Drawn Copper Wire, Specifications for	I Oper.—T. & T. Sec. IV Eng.—Elec. Sec.	J. A. Jones J. L. Minick

American Standards Association Technical Projects on Which the Association of American Railroads Is Now Co-operating—Continued

	ASA Project	**AAR Divisions, Sections and committees represented*	*Representative*
H16	Tinned Soft or Annealed Copper Wire for Rubber Insulation, Specifications for	I Oper.—T. & T. Sec. IV Eng.—Elec. Sec.	J. A. Jones J. L. Minick
M 7	Coal Mine Tracks, Signals and Switches	IV Eng.—Com. 5—Track	C. J. Geyer
M26	Clean Bituminous Coal, Specifications for	VI —Purchases and Stores	C. E. Smith
O 3	Cross-Ties and Switch-ties, Specifications for	IV Eng.—Com. 3—Ties	John Foley
O 4	Wood, Methods of Testing	IV Eng.—Com. 6—Buildings	W. T. Dorrance
O 5	Wood Poles, Specifications for	I Oper.—T. & T. Sec. IV Eng.—Elec. Sec.	J. D. Rogers Alt. H. A. Shepard Paul Lebenbaum
Z 2	Heads, Eyes and Respiratory Organs of Industrial Workers, Safety Code for the Protection of	I Oper.—Medical and Surgical Sec.	E. V. Milholland
Z 4	Industrial Sanitation, Safety, Code for	IV Eng.	R. C. Bardwell
Z 5	Ventilation Code	IV Eng.—Com. 6—Buildings	W. T. Dorrance
Z10	Letter Symbols and Abbreviations for Science and Engineering	IV Eng.—Sig. Sec. Elec. Sec.	E. K. Post Alt. H. G. Morgan Alt. J. H. Davis
Z11	Petroleum Products and Lubricants	IV Eng.—Const. & Maint. Sec.	J. G. Hartley
Z14	Drawing and Drafting Room Practice (Exclusive of Architectural Drawings) Standards for	IV Eng.—Com. 11—Records and Accounts	D. C. Teal
Z15	Graphic Presentation, Standards for	I Oper.—T. & T. Sec. IV Eng.—Com. 11—Records and Accounts	C. E. Baxter D. C. Teal
Z16	Methods of Recording and Compiling Accident Statistics, Standardization of	I Oper.—Safety Sec.	T. H. Carrow
Z23	Sieves for Testing Purposes, Specifications for	IV Eng.—Com. 8—Masonry	Meyer Hirschthal
Z26	Specifications and Methods of Test for Safety Glass	IV Eng.—Const. & Maint. Sec.	vacant
Z28	Work in Compressed Air	I Oper.—Medical and Surgical Sec. IV Eng.—Com. 8—Masonry	J. McCombe J. J. Yates
Z32	Graphical Symbols and Abbreviations for Use on Drawings	IV Eng.—Com. 11—Records and Accounts	vacant
Z35	Accident Prevention Signs, Specifications for	I Oper.—Safety Section	C. E. Hill

Appendix C

Canadian Engineering Standards Association
Ottawa

Activities—Year Ending March 31st, 1939

Publications

During the year the Association published 20 new standards or revisions to existing standards, as follows:

Section B—Mechanical Engineering

B44–1938—Safety Code for Passenger and Freight Elevators

Section C—Electrical Engineering

C10–1938—Tungsten Incandescent Lamps (second edition)
C50T–1938—Insulating Oils

C22.2 No. 7–1938—Portable Electric Displays and Incandescent Lamp Signs (second edition)
45–1938—Rigid Steel Conduit
46–1938—Electric Air Heaters
48–1938—Non-metallic Sheathed Cable
50–1938—Knife Switches
51–1938—Armoured Cable and Armoured Cord
56–1938—Flexible Steel Conduit

Section G—Ferrous Metals

G26–1938—Commercial-Quality Hot-Rolled Bar Steels (third edition)
G27–1938—Commercial Cold-Finished Bar Steels & Cold-Finished Shafting (third edition)
G30–1938—Billet-Steel Concrete Reinforcing Bars (third edition)
G31–1938—Rail-Steel Concrete Reinforcing Bars (third edition)
G32–1938—Cold-Drawn Steel Wire for Concrete Reinforcement (third edition)
G45–1938—Fabricated Steel Bar or Rod Mats for Concrete Reinforcement
G46–1938—Welded Steel Wire Fabric for Concrete Reinforcement

Section S—Steel Construction

S 6–1938—Steel Highway Bridges (third edition)
S47T–1938—Tentative Welding Qualification Code for Fabricators, Contractors, Supervisors and Welders.
S48T–1938—Tentative Electrode Specification for Electrode Manufacturers and Structural Steel Fabricators

The foregoing standards have been prepared with the cooperation and approval of producer and consumer interests, trade associations, educational institutions, the railways, insurance interests and interested departments of dominion and provincial governments.

During their preparation the appropriate committees made reference to analogous publications of the British Standards Institution, standardizing bodies of other British nations, the American Society for Testing Materials, the American Standards Association, the National Electrical Manufacturers' Association, Underwriters Laboratories, Inc., etc.

Progress Report

Standards Partially Completed

The following standards have been the subject of discussion by appropriate committees during the past year and such progress has been made that it is anticipated they will be published as new or revised CESA standards during the coming year.

Section A—Civil Engineering

A 5–1927—Portland Cement (Revision)
A57—High Early Strength Portland Cement
A23–1929—Concrete and Reinforced Concrete (Revision)
A16–1930—Steel Structures for Buildings (Revision)
(Note: A16 will be transferred to Section S—Steel Construction—in the new edition.)
A54—Procedure for Fire Tests for Building Construction & Materials
A55—Procedure for Tests for Fire Resistance of Roof Coverings
A56—Wood Piling and Pile Driving

Section B—Mechanical Engineering

B51—Canadian Regulations for the Construction and Inspection of Boilers and Pressure Vessels.
B52—Mechanical Refrigeration Code
B53—Colour Identification of Piping Systems

Section C—Electrical Engineering

C49—Aluminum Cable and Aluminum Cable Steel Reinforced

C58—Design of CESA Cast Lead-Pin Thread for Insulator Pins of Nominal Diameters of 1 in. and 1⅜ in.

C14–1924—Reinforced Concrete Poles (Revision)

C22.1–1935—Canadian Electrical Code, Part I (Inside Wiring Rules) Fourth Edition (Revision)

C22.2—Canadian Electrical Code, Part II (Approvals Specifications)
    No. 1(b)—Power-Operated Radio Devices (Conductively-Coupled Type)
        31—Switchboards
        47—Air-Cooled Transformers
        53—Washing Machines
        57—Pull-Off Plugs for Electro-thermal Appliances

C22.3—Canadian Electrical Code, Part III (Outside Wiring Rules)
    (a) Regulations for Supply and Trolley Lines Crossing Railways
    (b) Regulations for Communication Lines Crossing Railways

New Subjects Under Development

Authorization of the CESA Executive Committee for the investigation and preparation of standards has been given for the following subjects. Appropriate committees, subcommittees or panels have been organized for the purpose.

Section A—Civil Engineering

Building Brick
Structural Hollow Tile
Vitrified Clay Sewer Pipe
Lime
Gypsum Blocks
Concrete Blocks

Section B—Mechanical Engineering

Nominal Sizes & Standard Dimensions for Wood Screws
Copper & Brass Pipe
Copper Tubing
Cast Iron Pipe
Steel Pipe

Section C—Electrical Engineering

Oil Circuit-Breakers; Paper Insulated Lead-Covered Cable; Regulations for Communication Lines Crossing Supply & Trolley Lines; and the following Approvals specifications: Motors in Hazardous Locations (Classes I, II, III, & IV); Capacitors; Motors in Non-Hazardous Locations; Bell-Ringing, Signaling and Small Power Specialty Transformers; Motor-Operated Appliances (Portable Type with Fractional Horsepower Motors); Porcelain Insulating Devices; Service-Entrance Cable; Snap Switches; Electric Ranges; Cooking and Liquid Heating Appliances; Solderless Wire Connectors (Pressure Type); and revisions to Specifications No. 3, Electrical Equipment for Oil-Burning Apparatus; No. 9, Electric Fixtures; No. 14, Industrial Control Equipment in Ordinary (Non-Hazardous) Locations; No. 16, Insulated Conductors for Power-Operated Radio Devices; No. 25, Enclosures (Other than Explosion-Proof) for Use in Hazardous Locations; No. 28, Asbestos-Covered Wires; No. 42, Receptacles, Plugs and Similar Wiring Devices.

Section S—Steel Construction

Specification for Metallic Arc Welding (Bridges and Buildings).
Specification for Suitable Eye Screens for Welders.

Appendix D

Collaborating AREA Representatives on Committees American Society for Testing Materials

A–1 on Steel

4. E. E. Chapman
4. Robert Faries
13. Ray McBrian
15. G. H. Tinker

A–5 on Corrosion of Iron and Steel

1. W. C. Pruett
1. A. R. Jones
13. J. J. Laudig
15. A. W. Carpenter

B–2 on Non-Ferrous Metals and Alloys

1. W. C. Pruett
1. A. R. Jones
15. James Aston

B–5 on Copper and Copper Alloys, Cast and Wrought

15. C. H. Mercer

C–1 on Cement

8. M. Hirschthal
8. A. N. Laird
8. J. F. Leonard

C–9 on Concrete and Concrete Aggregates

8. W. K. Hatt
8. M. Hirschthal

C–12 on Mortars for Unit Masonry

8. W. M. Ray

C–13 on Concrete Pipe

8. Theodore Doll
8. J. F. Leonard
15. G. A. Haggander

D–7 on Timber

7. C. J. Hogue
7. J. A. Newlin
17. E. B. Fulks

D–8 on Bituminous Waterproofing and Roofing Materials

Wpfg. J. A. Lahmer

D–19 on Water for Industrial Use

13. R. C. Bardwell
13. J. J. Laudig

Note—Numbers in front of names designate AREA committees.

Report of Committee 18—Electricity

H. F. BROWN, *Chairman,*
D. J. BRUMLEY
D. M. BURCKETT
F. W. GARDINER
PAUL LEBENBAUM
W. L. MORSE
R. J. NEEDHAM
S. R. NEGLEY
A. E. OWEN
H. W. PINKERTON
D. B. THOMPSON, *Vice-Chairman,*
W. M. VANDERSLUIS
R. P. WINTON
Committee.

To the American Railway Engineering Association:

Your committee respectfully reports on the following subjects:

1. Developments in the application of electricity to railway service (Appendix A). Progress report.

2. The principal current activities of the Electrical section, Engineering division, by synopsis, supplemented with list and reference by number of adopted specifications, designs and principles of practice (Appendix B). Progress report.

THE COMMITTEE ON ELECTRICITY,
H. F. BROWN, *Chairman.*

Appendix A

(1) Developments in the Application of Electricity to Railway Service

While there have been no spectacular or outstanding developments in the application of electricity to railway service since the last report of this committee, each year sees refinements of the achievements of previous years and the more extended use of newly developed apparatus and methods.

The carriers having electrified lines are finding additional advantages and increased flexibility in operation with electric motive power, particularly on lines that handle dense freight traffic. No notable extensions to electrified track or new purchases of electric motive power have been placed in service during the past 12 months.

Numerous improvements in the illumination of new car equipment have been made during the year, especially in the application of the fluorescent lamp, mentioned in last year's report for the first time.

Electric air-conditioning equipment has been improved—and its use extended—both on cars and for terminal servicing equipment. One carrier has developed a portable substation for temporarily servicing parked Pullman cars when normal facilities are over-taxed, for example, during large conventions.

Continued improvement has been made in the design of electrically-operated shop tools, welding equipment and electrically-operated roadway maintenance tools, and their use has been extended.

It seems logical to assume that with the development and growth of such large power projects as Boulder dam, Grande Coulee and others, together with the steady growth in power transmission networks, the railroads will share with industrial and rural users the more extended use of electric power for their various requirements.

Bulletin 413, November, 1939.

Appendix B

(2) The Principal Current Activities of the Electrical Section, Engineering Division

The reports of the committees of the Electrical section, Engineering division, have been published in Bulletin 412, September-October, 1939, and, therefore need only be summarized here. Since no meeting of the section had been held for two years (from October, 1937, to October, 1939,) the reports of the committees are primarily statements of progress. These and the reports published in Bulletin 405, September-October, 1938, should be studied together.

Power Supply

The Committee on Power Supply has referred again to the national power survey of the Federal Power Commission, submitted revised tabulated data on characteristics of electric power supply facilities installed by various carriers for servicing air-conditioned cars, and submitted a proposed form of contract for the purchase of electric energy, action on which was withheld for the purpose of avoiding conflict with similar instruments in the Manual of the AREA.

Electrolysis

The committee refers to its 1938 report.

Overhead Transmission Line and Catenary Construction

The committee has advanced its work on Manual revision and wire specifications.

Standardization of Apparatus and Material

The committee has revised its list of ASA standards of interest to the section; submitted proposed comprehensive specifications for rubber insulated wires and cables, varnished cloth insulated wires and cables, impregnated paper insulated wires and cables, and for fiber conduit and asbestos duct for electrical purposes.

Electric Heating and Welding

The committee refers to its 1938 report.

Application of Motors

The committee has continued to co-operate with the Electrical section of the Mechanical division. Reference is also made to the use of fibrous glass for motor insulation.

Clearances for Third-Rail and Overhead Working Conductors

The committee has endeavored to advance the adoption of the clearance diagram for overhead working conductors.

Protective Devices and Safety Rules in Electrified Territory

The report is confined principally to the matter of "Recommended practice for the prevention of electric sparks that may cause fire during the transfer of inflammable liquids to or from rail equipment", looking toward a revision of AAR Circular ES-3.

Specifications for Track and Third-Rail Bonds

The report presents additional experience with various test bond installations, and outlines in detail the bonding of the third-rail and track rails of the San Francisco-Oakland Bay Bridge Railway. The committee also refers to the report of the Heavy Electric Traction committee of the American Transit Association.

Illumination

The committee reports rapid progress in the development of the fluorescent lamp; it also reports on "heating" lamps for producing infra-red rays, which are useful for heating and drying purposes.

Design of Indoor and Outdoor Substations

The report covers maintenance methods, the painting of large transformers by the flow method, high-voltage insulator testing, and submits a detailed account of the relay protection of the electric power supply system of the Pennsylvania Railroad, similar to previous reports on the relaying as applied to other electrified lines, submitted during the past few years by this committee.

High Tension Cables

The committee reports developments in gas pressure impregnated paper insulated cables, citing two experimental installations in or near New York City.

Application of Corrosion Resisting Materials to Railroad Electrical Construction

The committee reports the conclusion of the Hemphill Tunnel tests, with quantitative tabulated data and photographs of the corrosion found in various ferrous and non-ferrous materials tested.

Manual

A special committee on Manual review also reports this year and makes recommendations as to changes and revisions necessary to the Manual of the Electrical section.

While not specifically mentioned in the report, the Electrical section has been active this year in the inauguration of a special committee for co-ordinating the work of the various sections of the AAR interested in electrical and allied matters, which should be instrumental during the future in assuring unanimity of opinion, and prevent overlapping and duplication of effort in the work of the various sections in these matters.

Report of Committee 10—Signals and Interlocking

H. G. Morgan, *Chairman,*
F. H. Bagley
G. H. Dryden
W. J. Eck
W. H. Elliott
P. M. Gault
C. R. Hodgdon
J. C. Mock
R. D. Moore
F. W. Pflecing
W. M. Post
A. H. Rudd
J. E. Saunders
H. L. Stanton
H. H. Orr, *Vice-Chairman,*
E. G. Stradling
C. A. Taylor
G. K. Thomas
C. H. Tillett
W. M. Vandersluis
F. B. Wiegand
Committee.

To the American Railway Engineering Association:

Your committee respectfully reports on the following subjects:

1. Development in railway signaling (Appendix A). Progress report.

2. The principal current activities of the Signal section, AAR, by synopsis, supplemented with list and reference by number of adopted specifications, designs and principles of signaling practice (Appendix B). Progress report.

The Committee on Signals and Interlocking,
H. G. Morgan, *Chairman.*

Appendix A

(1) Development in Railway Signaling

W. M. Post (chairman, subcommittee), G. H. Dryden, W. J. Eck, J. C. Mock, C. A. Taylor, C. H. Tillett.

Coded Track Circuits—11,000 ft. Long

A recent development is the introduction of the 11,000 ft. coded track circuit. It uses coded d.c. track circuit energy and retains all of the advantageous characteristics of coded track circuit control, namely, no line wires are required; good shunting sensitivity is provided; it maintains protection against foreign current and it has a high degree of safety, inherent in the use of coded energy.

This new application of coded track circuit control can by the use of different frequency of impulses per minute give three or four signal indications, and approach lighting, without line wires and is adaptable to either primary or storage-battery operation. An 11,000-ft. coded track circuit requires that the track joints be bonded so that the rail resistance will not exceed 0.04 ohms per 1,000 ft. of track.

With an 11,0000-ft. track circuit, it is possible to operate two-mile automatic blocks without cut sections. While the first installation was made over a year ago, there are about 18 circuits in service at the present time.

Bulletin 413, November, 1939.

Appendix B

(2) The Principal Current Activities of the Signal Section, AAR, by Synopsis

Supplemented With List and References by Number of Adopted Specifications, Designs and Principles of Signaling Practice

W. M. Post (chairman, subcommittee), G. H. Dryden, W. J. Eck, J. C. Mock, C. A. Taylor, C. H. Tillett.

Current Activities of the Signal Section, AAR, Since November, 1938

There are now available 22 of a series of 24 pamphlets on American Railway Signaling Principles and Practices prepared for the education of signal men and others desiring to study this subject.

The work performed during the fiscal year of 1938 and reported at the 1939 Annual Meeting covers the following subjects:

1. Costs involved in stopping trains.
2. Modernizing automatic block signals on the Chicago & North Western Railway.
3. Automatic interlocking on the Atchison, Topeka & Santa Fe Railway, the Canadian National Railways, the Chicago, Milwaukee, St. Paul & Pacific Railroad, and the Chicago, Rock Island & Pacific Railway.
4. Remote control interlocking on the Louisville & Nashville Railroad.
5. Economic value of battery lighted switch lamps.
6. Protection of traffic against slides and rock falls.
7. Activities of radio communication for railroad purposes—co-operative report.
8. Automatic train control and cab signals.
9. Dominion activities—automatic train control and signals.
10. Requisites for a. c. and d. c. coded signal systems.
11. Requisites for protection of oil sidings.
12. Development of proposed inductive co-ordination measures involving railroad power lines and power equipment, as a result of the adoption of the principles and practices for the inductive co-ordination of railway electric supply facilities and the communication facilities of the Bell System—co-operative report.
13. Instructions for adjustment of electric lever locks and mechanical locking to insure operating margin.
14. Circuit design to reduce the number of line wires.
15. Terminal connectors—drawing.
16. Pipe flanges and fittings—co-operative report.
17. Simplification and standardization of electric lamps for signal purposes.
18. Standardization of color glasses.
19. Certified duplicate limit glasses.
20. Electrical insulating materials in general—co-operative report.
21. Harmonizing sections covering binding posts in specifications.
22. Development on highway grade-crossing protection.
23. Corrective measures to minimize or eliminate phantom indications of flashing light signals.
24. State and Federal activities—highway grade crossing protection.
25. Modifications of the National Electrical Safety Code to avoid confliction with recognized signal practice.

26. Specification for rubber insulation for signal wires, utilizing the latest developments in the art, such as anti-oxidents and organic accelerators.

27. Non-inflammable insulation for wire for use in signal stations.

28. Requisites for centralized switch-tender control.

29. Proper aspect for train-order signals combined with automatic signals and interlocking plants.

30. Aspects and indications for four-block signal systems.

31. Approach indications for train order signals.

32. Signaling in England.

SPECIFICATIONS REVISED

	Old No.	*New No.*
Hard Fiber	13–35	13–39
Direct-Current Generator	1432	14–39
Galvanized E.B.B. Steel Bonding Wire	2232	22–39
Channel Pins	23–37	23–39
Galvanizing for Iron or Steel	2912	29–39
Galvanized Copper-Bearing Steel Line Wire	32–12A	none
Enameled Round Copper Magnet Wire	4113	none
Direct-Current Vibrating Highway Crossing Bell	44–35	44–39
Transformer Oil	4631	46–39
Steel Guy and Messenger Strand	4714	none
Nickel, Iron, Alkaline Storage Battery	49–34	49–39
Incandescent Electric Lamps	5115	51–39
Low-Voltage Lightning Arrester	52–35	52–39
Lead Acid Stationary Storage Battery (Plates of Composite Structure)	53–34	53–39
Aerial Aluminum Cable Steel Reinforced	54–34	54–39
Trunking and Capping (Wood)	5728	57–39
Lead Acid Stationary Storage Battery (Plates of Pure Lead)	58–34	58–39
Kerosene Hand Lantern Globes	59–38	59–39
Installation of Made Ground for Protection Against Abnormal Potentials	6031	60–39
Signal Glasses	69–38	69–39
Forty-Percent Conductivity Copper-Covered Steel Bonding Wire	7032	70–39
Alternating Current Generator	7332	73–39
Impedance Bond	7432	74–39
Mechanical Interlocking Machine, S. & F. Locking	75–36	75–39
Electric Interlocking Machine	76–36	76–39
Alternating Current Relay	78–37	78–39
Electric Motor Semaphore Signal	7933	79–39
Electric Color-Light Signal	8029	80–39
Electric Position-Light Signal	81–34	81–39
Air-Cooled Transformer	83–35	83–39
Transformer, Oil-Immersed, Self-Cooled	84–37	84–39
Portable Direct Current Voltmeters, Ammeters and Volt-Ammeters	85–36	85–39
Type "A" Copper-Oxide Caustic Soda Primary Cell	87–36	87–39
Aerial Braided Cable	8933	89–39
Armored Submarine Cable	9032	90–39
Lead-Covered Cable	9132	91–39
Universal Switch Circuit Controller	9530	95–39
Fuses	9633	96–39
Electric Locks	99–36	99–39
Electric Motor Switch Operating Mechanism	101–36	101–39
Zero Fahrenheit Lubricating Oil	10220	102–39
45 Degrees Below Zero Fahrenheit Lubricating Oil	10320	103–39
Air-Cooled Reactor for Line and Track Circuits	10432	104–39
Tractive Armature Direct Current Neutral Relay with Two or More Contact Fingers	105–37	105–39

	Old No.	*New No.*
Resistor	10628	106–39
Switchboard	107–37	107–39
Mineral Matter Rubber Compound Insulated Wire	11133	111–39
Portable Alternating Current Ammeter	112–35	112–39
Battery Jar (Primary)	11328	113–39
Mechanical Interlocking Machine, Style "A" Locking	114–36	114–39
Portable Alternating Current Voltmeter	115–35	115–39
Wiring	11929	119–39
Paint and Painting	12022	120–39
One-Inch Welded Steel Pipe	12227	122–39
One-Inch Welded Wrought Iron Pipe	123–36	123–39
Mechanical Time Release	128–35	128–39
Circuit Controller for Drawbridges	130–38	130–39
Electro-Mechanical Interlocking Machine	134–38	134–39
Track Circuit Rail Bonding	135–38	135–39
Oil Lighted Lamp	13726	137–39
Interlocking Lever Circuit Controller	138–35	138–39
Preservative Treatment of Capping and Grooved Trunking	14026	140–39
Dry Process Porcelain Insulation	144–36	144–39
Parkway Cable-Mineral Matter Rubber Compound Insulated Wire	14532	145–39
Pin Type Porcelain Insulators	14631	146–39
Alternating Current Power Transfer Relay	148–37	148–39
Centralized Traffic Control Machine	150–37	150–39
Plug Type Rail Bonds and Track Circuit Connectors	151–38	151–39
Electro-Pneumatic Switch Operating Mechanism	152–38	152–39
Tractive Armature Direct-Current Neutral Relay for Series Line Approach Lighting	154–37	154–39
Railroad Highway Grade-Crossing Signs	155–37	155–39
Reflector Unit	156–37	156–39
Electric Color-Light Signal Operating Mechanism, Searchlight Type	157–34	157–39
Lead Acid Stationary Storage Battery (Plates of Alloy Composition)	158–34	158–39
Brass and High Tensile Strength Metals and Alloys for Binding Posts, Machine Screws, Nuts, Washers, etc., Used in Signal Apparatus	159–35	159–39
Capacitor for Power Factor Correction	160–35	160–39
Fibrous-Covered Non-Metallic Sheath for Railway Signal Cable	161–37	161–39
Electric Color-Position-Light Signal	162–35	162–39
Weatherproof Covering for Line Wire	163–35	163–39
Tractive Armature Direct Current Polarized Relay	165–36	165–39
Copper-Oxide Rectifiers and Valves	166–36	166–39
Bare Copper-Covered Steel Line Wire, Thirty Percent Conductivity	167–36	167–39
Bare Copper Alloy Line Wire, Thirty Percent Conductivity	168–36	168–39
Bare Hard-Drawn Copper Line Wire	169–36	169–39
Air Depolarized Cell	170–36	170–39
Type "B" Copper-Oxide Caustic Soda Primary Cell	171–36	171–39
Copper-Covered Steel Guy and Messenger Strand	173–37	173–39
Electric Lamp Case	174–38	174–39
Insulating material for Filling and Sealing Recesses in Signal Apparatus	177–37	177–39
Welded Type Rail-Head Bonds and Track-Circuit Connectors	178–38	178–39
Mechanically Applied Rail-Head Type Bonds and Track-Circuit Connectors	179–38	179–39
Weather-Resisting Braid Coverings for Aerial, Rubber-Insulated Wire and Cable	182–38	182–39
Gray Iron Castings	none	none
No. 6 Dry Cell	none	none
Refined Iron Bars (formerly Wrought Iron Bars)	none	none

DRAWINGS REVISED

	Old No.	*New No.*
Foundation for Ground Mast Signals	1107B	1107C
Concrete Battery Box—Assemblies	1266A	1266B
Concrete Battery Box—Details	1267A	1267B
Concrete Battery Box—Details	1268A	1268B
Concrete Battery Box—Details	1269A	1269B
Base for 4-Inch Mast	1449	1449B
Hand Lantern Globes	1611C	1611D

REQUISITES REVISED

Mechanically Locking the Levers of Interlocking Machines.

INSTRUCTIONS REVISED

Inspecting and Testing Mechanical Locking of an Interlocking Machine.

NEW SPECIFICATIONS

	No.
Centralized Traffic Control Detachable Type Neutral Direct-Current Relay	180–39
Paint and Painting of Braid-Covered Aerial Wires and Cables—Cable Paint—Volatile Thinner	181–39
Multiple-Unit Terminal Block	183–39
Flasher Relay	185–39
Tractive Armature Direct-Current Neutral Interlocking Relay	186–39
Paint and Painting of Braid-Covered Aerial Wires and Cables—Cable Paint—Asphalt or Coal Tar Emulsion	187–39

NEW DRAWINGS

Multiple-Unit Terminal Block	1054A
250 a.h. Primary Battery Jar	1418A
Highway-Crossing Sign—50-Deg. Reflector Type	1691A
50-Deg. Reflector Crossing-Sign Assembly	1692A
50-Deg. Reflector Crossing-Sign Details	1693A
Precast Foundation for Four-Inch Mast—Details and Assemblies	1694A
Precast Foundation for Four-Inch Mast—Details	1695A

NEW REQUISITES

Track Welding or Heat Treating in Track-Circuit Territory.
Automatic Gates—Highway Crossings at Grade over Railway Tracks.

NEW MISCELLANEOUS MATTER

Stringing Sags for New Line Wire.

DRAWINGS REMOVED FROM THE MANUAL

Single Switch Assembly: Attachment—Operating and Front Rods	1531
Movable Point Frog Assembly: Attachment—Operating and Front Rods	1532
Double Slip Switch Assembly: Attachment—Operating and Front Rods	1533
Hand Lantern Globes	1610A

MISCELLANEOUS MATTER REMOVED FROM THE MANUAL

Insulation Resistance in Megohms per Mile at 60 Deg. F.

Report of Committee 20—Uniform General Contract Forms

W. G. Nusz, *Chairman,*	N. D. Hyde	J. S. Lillie, *Vice-Chairman,*
E. H. Barnhart	J. C. Irwin	F. L. Nicholson
Clark Dillenbeck	F. R. Layng	C. B. Niehaus
W. D. Faucette	S. L. Mapes	H. A. Palmer
J. P. Hanley	A. A. Miller	W. M. Post
G. B. Harris, Jr.	O. K. Morgan	W. R. Swatosh
B. Herman		*Committee.*

To the American Railway Engineering Association:

Your committee respectfully presents its report on the following assignments:

1. Revision of Manual. All of the uniform general contract forms were very carefully revised prior to the publication of the present Manual; they have been reviewed during the current year and no revisions are recommended at this time.

2. Form of agreement to cover operation of commissary and boarding outfits. The committee presented, at the last convention of the Association, a tentative form of agreement, as information. The few suggestions have been carefully considered and the committee now presents a form of agreement for adoption by the Association as recommended practice (Appendix A).

3. Form of agreement for commercial signs on railway property. The committee has prepared a form of agreement and it is submitted as information and for discussion with the recommendation that the subject be continued (Appendix B).

4. Form of lease for air-right development. The committee has collected a number of agreements and a large amount of information covering this assignment. Considerable progress has been made but no form of agreement is presented at this time. It is expected to make a definite recommendation to the Association next year and it is recommended that the subject be continued.

5. Form of agreement for electrified fence along right-of-way. This is a new assignment, information is being collected on the subject and progress has been made. It is recommended that this be continued.

6. Form of blanket agreement for wire line crossing. The Association of American Railroads, at the request of the Federal Rural Electrification Administration, appointed a special committee to study this subject. The special committee included certain members of Committee 20. The AAR special committee has completed a form of agreement which is presented to the Association as information only (Appendix C).

The Committee on Uniform General Contract Forms,

W. G. Nusz, *Chairman.*

Bulletin 413, November, 1939.

Appendix A

(2) Form of Agreement to Cover Operation of Commissary and Boarding Outfits

W. R. Swatosh (chairman, subcommittee), E. H. Barnhart, J. P. Hanley, B. Herman, F. R. Layng, A. A. Miller, W. M. Post.

A tentative form of this agreement was submitted to the Association as information in Bulletin 406, 1938. Since that time the few suggestions received have been carefully considered, the agreement has been entirely rewritten, and the following draft is presented for approval of the Association and printing in the Manual.

FORM OF AGREEMENT FOR OPERATION OF COMMISSARY AND BOARDING OUTFITS

1940

THIS AGREEMENT, made this .... day of ...., 19...., by and between ...., a corporation organized and existing under the laws of the State of ...., hereinafter called the Railway Company and ...., hereinafter called the Contractor.

WITNESSETH:

WHEREAS, the parties hereto deem it to their mutual interest that the housing, feeding and provisioning of certain employees should be regularly effected under a contract between the parties hereto;

NOW THEREFORE, in consideration of the covenants and agreements herein contained, to be performed by the parties hereto and of the payments hereinafter agreed to be made, it is mutually agreed as follows:

THE CONTRACTOR COVENANTS AND AGREES

1. Contractor's Control

To assume control of and conduct in a manner at all times satisfactory to the .... of the Railway Company, commissaries or boarding camps for employees of the Railway Company.

2. Contractor's Employees

To employ and provide at its own expense such employees as may be necessary to conduct said commissaries or boarding camps in a proper and business-like manner, to the satisfaction of the .... of the Railway Company.

3. Camp Equipment

To furnish at its own expense all cooking utensils, dishes, tableware, mattresses and springs and keep all equipment furnished or used clean and in good sanitary condition.

4. Maintenance of Camp

That it shall at its own expense maintain said commissaries or boarding camps and premises surrounding same in good sanitary condition, free from filth and rubbish, and maintain each or both of them so as to fully meet the requirements of the local health officers or other public authorities having jurisdiction over commissaries or boarding camps.

5. Abandonment of Camps

That upon the abandonment of any camp it will leave the surrounding premises in a good, clean condition satisfactory to the .... of the Railway Company.

6. Charges Against Railway Company Employees

That it will not charge the hereinbefore mentioned employees for lodging or rental of boarding camp or equipment in camps, where the housing accommodations and equipment are furnished by the Railway Company, except for malicious damage or destruction of same.

7. Stocking Commissaries

To keep said commissaries stocked at all times with supplies, needed by said employees, which supplies shall be sold to them at not more than the prevailing retail prices.

8. Meals

To furnish to said employees meals approved by the .... of the Railway Company, consisting of good, wholesome, nutritious and well-cooked food of well balanced variety.

9. Alcoholic Beverages and Drugs

To prohibit the vending, and not itself vend or furnish to said employees (including its own employees) any alcoholic beverages or harmful drugs within the Railway Company's right of way, the confines of the camp, or adjacent territory under its control.

10. Compliance with Laws

To save the Railway Company harmless from any or all claims or liability for loss, damage or penalties for violation of any order or regulation of governmental authorities having jurisdiction or of any law or ordinance, due to the acts or neglect of the Contractor or his agents or employees in connection with the conducting of said commissary or boarding camp.

11. Fire Inspection

That the .... of the Railway Company or his authorized representative may at any and all times inspect Commissaries or Boarding Camps in order to determine if adequate safeguards against fire hazards have been established. If in his opinion such safeguards are considered insufficient he will instruct the Contractor as to additional protection required. The Contractor shall fully comply with such instructions.

12. Liability and Risk

(a) To indemnify and save harmless the Railway Company and other companies and facilities on its property from any and all loss or damage to property and injury to or death of persons, or any suits, claims, liability or demands in connection therewith, however caused, resulting directly or indirectly from the housing, feeding and provisioning of aforesaid employees, unless due to the sole negligence of the Railway Company.

(b) To assume all risk of loss or damage to property of the Contractor, however caused, resulting directly or indirectly from the housing, feeding and provisioning of aforesaid employees, and hereby releases the Railway Company from all liability on account of such loss or damage, whether or not the negligence of the Railway Company contributed thereto in whole or in part.

13. Bond

That upon the execution and delivery of this agreement, and before taking effect of the same in other respects, furnish and deliver to the Railway Company a written bond of indemnity to the amount of .... Dollars in form and substance and with surety thereon satisfactory and acceptable to the .... of the Railway Company, to insure the faithful performance by the Contractor of all the covenants and agreements on the part of the Contractor contained in this agreement.

14. Cost to Employees

That the price of service and meals is hereby fixed as the date of this agreement at $............... for service per week per man and ....¢ per meal per man. Such prices may, however, be changed from time to time by written agreement between the Contractor and the .... of the Railway Company. The Contractor shall furnish for approval of the .... of the Railway Company a schedule of the services to be performed by it and the prices of each including price per meal.

THE COMPANY COVENANTS AND AGREES

15. Equipment, Lamps, Fuel and Water

To furnish at such commissaries or camps the necessary buildings or cars properly equipped with bunks, stoves, including cooking ranges, ice boxes, chairs, tables, fuel, water, lamps and such sanitary facilities as may be required for reasonable comfort and sanitation.

16. Transportation

That so far as it lawfully may, furnish free transportation on the lines of the Railway Company on suitable trains, to the officers, agents and employees of the Contractor when traveling solely on the business of operating commissaries or boarding camps. The Railway Company will furnish transportation for supplies, when such supplies are in camp cars that are to be moved from one designated location to another for use on the lines of the Railway Company.

17. Track Cars

Nothing in this agreement shall be construed as giving any officer or employee of the Contractor the right to use or ride upon track cars.

THE CONTRACTOR AND THE RAILWAY COMPANY MUTUALLY COVENANT AND AGREE

18. Statement to Railway Company

That the Contractor shall furnish the .... of the Railway Company on the fifteenth (15th) and last day of each month an itemized bill, properly certified, covering supplies, meals or service furnished each employee and the Railway Company agrees that it will thereupon deduct from the wages due said employees respectively, at the end of each pay period the proper amount due the Contractor for supplies, meals and service during that period, and will pay over such amount to the Contractor, provided there shall be a sufficient amount due the employee, after deducting the Railway Company's own prior items, such as hospital dues, insurance, retirement and social security taxes, etc.

19. Railway Company's Control

The Railway Company reserves the right to designate what points, what work and what employees shall come within the scope of this contract. The Railway Company further reserves to each employee the right to find or provide his own meals and lodging.

20. Independent Contractor

That the Contractor shall be and remain an independent Contractor with respect to all services performed hereunder and agrees to and does hereby accept full and exclusive liability for the payment of any and all contributions or taxes for social security, unemployment insurance, or old age retirement benefits, pensions, or annuities now or hereafter imposed under any state or federal law which are measured by the wages, salaries or other remuneration paid to persons employed by the Contractor on work performed under the terms of this agreement and also agrees to indemnify and save harmless the Railway Company from any such contributions or taxes or liability therefor.

21. Inspection

That the .... of the Railway Company or his authorized representative may at any and all times inspect said commissaries, equipment, supplies and food.

22. Titles of Articles and Sections

All titles of articles and sections printed in bold face type are inserted for purposes of convenience only, and shall not be considered a part of this agreement, nor be used in any manner as an aid to the interpretation thereof.

23. Cancellation

This agreement shall continue in force for a period of .... from the date hereof, and thereafter until terminated by either party hereto giving to the other party at least thirty (30) days previous notice in writing of such cancellation or termination.

In Witness Whereof, the parties hereto have caused this agreement to be executed on the day and year first above written.

Attest: ....Railway Company

.... By ....

Secretary

Witness: ....Contractor

.... By ....

Appendix B

(3) Form of Agreement for Commercial Signs on Railway Property

O. K. Morgan (chairman, subcommittee), G. B. Harris, Jr., N. D. Hyde, J. S. Lillie, S. L. Mapes, C. B. Niehaus, H. A. Palmer.

Your committee has collected a large amount of data on this subject and presents the following form as information and for discussion.

FORM OF AGREEMENT FOR COMMERCIAL SIGNS ON RAILWAY PROPERTY

THIS AGREEMENT, made this .... day of ...., 19...., by and between ...., a corporation organized and existing under the laws of the State of ...., hereinafter called the Railway Company, and ...., hereinafter called the Licensee:

Witnesseth:

The Licensee desires to construct, maintain and use a commercial sign upon the property of the Railway Company situated at .... and substantially as shown on the plan and in the specifications hereto attached, designated as .... dated .... and made a part hereof:

It is mutually agreed as follows:

1. Grant

The Railway Company grants permission to the Licensee to construct, maintain and use a .... sign upon the property of the Railway Company, in accordance with said plan and the specifications forming a part hereof, and subject to the requirements of the Railway Company.

2. Display Copy

The permission herein granted is upon the express condition that any sign erected and advertising displayed thereon during the term of this agreement shall be in substance, form, kind and character satisfactory to and approved by the .... of the Railway Company, and upon any breach of this condition by said Licensee, such license shall terminate at once.

3. Permits and Taxes

Prior to the erection of said sign the Licensee shall, at its sole cost and expense, procure all necessary consents and permits from any Municipal, State and Federal authorities having jurisdiction, and shall pay all license fees and taxes, or increase of taxes, assessed against or imposed on or by reason of said sign, and at all times during the continuance hereof, shall comply with all rules, regulations and requirements of said authorities and of the National Board of Fire Underwriters relative thereto.

4. Cost and Maintenance

The Licensee shall at its sole cost and expense, in a manner satisfactory to the .... of the Railway Company, construct and maintain said sign and keep the land and buildings appurtenant thereto in a cleanly condition, free of litter and refuse matter occasioned by said sign, at all times during the continuance of this agreement.

5. Changes of Structures

The Licensee further covenants and agrees that if and in case the location of the sign should in the opinion of the Chief Engineer of the Railway Company require the strengthening of any building, roof, sidewall or appurtenance thereto, or increase the load so as to require additional support, or to cut through any roof for the attachment of said sign or its supports, the same shall be done and said alterations thereafter maintained during the term of this agreement by the Licensee at its sole cost and expense, and to the satisfaction of the Chief Engineer of the Railway Company.

6. Removal

Upon notice of termination of the license, the Licensee shall at once and at its sole cost and expense remove said sign and restore, if requested by the .... of the Railway Company, the Railway Company's property to its former condition; and if the Licensee within .... days shall fail so to do, said sign shall forthwith become the property of the Railway Company, and all right, title and interest therein of the Licensee shall terminate, or the Railway Company may, at its option, remove said sign and restore the Railway Company's property to its former condition at the sole cost and expense of the Licensee, which cost and expense the Licensee covenants and agrees to pay upon demand.

7. Rentals

The Licensee shall pay as rental therefor .... Dollars ($............) per annum, in advance, for each year and at the same rate for any part of a year unexpired at the termination of this license.

8. Liability

The Licensee shall not in any way or at any time interfere with the safe passage of the Railway Company's trains; and shall indemnify and save harmless the Railway Company from any and all damage, loss or injury, including injury resulting in the death of any person whomsoever, suits, claims, liabilities, recoveries, or demands resulting directly or indirectly from the installation, maintenance, use or existence of said sign, whether caused by the negligence of the Railway Company or otherwise.

9. Risk

The Licensee assumes all risk of loss or damage to its property on the premises of the Railway Company, however caused, and hereby releases the Railway Company from all liability on account of such loss or damage.

10. Term

This agreement shall continue in force for .... years, and thereafter from year to year until terminated by either party giving to the other .... days' notice in writing at the last known address, of its intention so to do and upon the expiration of the time mentioned in such notice this agreement shall terminate.

11. Assignment

This agreement shall not be assigned or in any manner transferred without the written consent of the .... of the Railway Company.

Until terminated as herein provided, this agreement shall inure to the benefit of and be binding upon the legal representatives and successors of the parties respectively.

In Witness Whereof, the parties hereto have executed this agreement in ...., the day and year first above written.

.... Company

Attest .... By ....

Secretary

.... Licensee

Witness .... By ....

Appendix C

(6) Form of Agreement For Wire Line or Cable Crossings

F. L. Nicholson (chairman, subcommittee), W. D. Faucette, S. L. Mapes, W. M. Post, W. R. Swatosh.

At the request of the Federal Rural Electrification Administration through Mr. J. M. Symes, vice-president, Operations and Maintenance, AAR, our then president, Mr. F. E. Morrow, on November 11, 1938, appointed a committee consisting of five representatives of Construction and Maintenance section; five representatives for Electrical section and one for Telegraph and Telephone section, "to prepare a Uniform Contract and Specifications governing wire crossings as a basis of meeting the requirements of the Rural Electrification Administration which will be satisfactory to the railroads generally."

The first meeting of this committee was held in the offices of the AAR on November 15, 1939, and the committee drafted a Form of Application, Form of Agreement, Scale of Fees and Rentals, and Specifications, after which a meeting was held with a committee of the Rural Electrification Administration and these drafts discussed. A second meeting was held on January 11, 1939; the forms and specifications were again considered and revised in so far as possible to meet the views of the representatives of the Administration. The final drafts of Form of Application, Form of Agreement and Scale of Fees and Rentals are herewith submitted. These have not been approved either by the Administration or by the Association of American Railroads. It is expected that another meeting will be held, we hope, for a final consideration and recommendation.

These forms are submitted as information with the request that the members of this Association bring them to the attention of the proper officer of their management with the recommendation that they either be adopted as prepared, or that the principles represented therein be adopted and used in any agreements they prepare. It appears as most desirable to all concerned that some uniform practice be adopted; there is at this time no uniformity in practice for making such agreements.

FORM OF AGREEMENT FOR WIRE OR CABLE LINE CROSSINGS

THIS AGREEMENT, made this .... day of ...., 19..., by and between the (Railway Company), a corporation organized and existing under the laws of ...., hereinafter called the Railway Company, and ...., hereinafter called the Licensee.

Witnesseth:

Whereas, the Licensee desires to construct, maintain and use wire or cable lines and appurtenances for transmission of electric energy over or under and across the property, tracks and wires of the Railway Company, and over or under and across the wires of such other party or parties as Railway Company has permitted to place on its property, the location of such construction to be substantially as shown on plan and elevation on approved drawings, similar to Exhibit "A" hereto attached, identified by the signature of ...., for the Railway Company, and of ...., for the Licensee, and are to be filed with the Railway Company and thereby made a part hereof.

It is mutually agreed as follows:

1. Grant

The Railway Company so far as it may lawfully so do grants the Licensee permission to construct, maintain and use said construction over or under and across the property, tracks and wires of the Railway Company, and the wires of such other party or parties as Railway Company has permitted, or may permit, to place wires on its property, but not parallel to the Railway Company's tracks and wires, at such location plan and elevation as indicated on approved drawings and subject to requirements of the Railway Company.

2. Specifications

The Licensee shall install and maintain said construction under the supervision and direction and to the satisfaction of the .... of the Railway Company, or his authorized representative and, except in cases of emergency, shall do no work with reference to the construction, reconstruction or maintenance of said construction on the Railway Company's premises, except under such supervision and direction, and after reasonable notice given in writing to the .... of the Railway Company.

The Licensee shall reimburse the Railway Company for any and all expense that may be incurred by the Railway Company in connection with said construction.

Said construction and maintenance thereon shall accord with the latest requirements of "Specifications for Electric Light, Power Supply and Trolley Wires Crossing Railways", as from time to time approved by the Association of American Railroads and printed in the Manual of its Electrical Section, Engineering division.

If, in any particular, said specifications conflict with the laws of the State in which the construction is to be placed, then said specifications shall be modified only to the extent necessary to meet the State law, and in all remaining particulars said specifications shall govern.

3. Use

The Licensee shall use the said construction solely for the purpose of conveying electric energy at the potential not in excess of that shown in each case on approved drawings, and shall make no change without first securing approval of the .... of the Railway Company.

4. Protection of Existing Circuits

The Licensee shall protect the telegraph, telephone, signal and other circuits on, over, under or adjacent to property of the Railway Company from electrical or other interference or damage by or because of said construction, and shall construct, maintain and use said construction in such a manner as will not damage or injuriously affect the use of telegraph, telephone, signal or other circuits of the Railway Company or of other

Companies that may now or hereafter have the right to maintain such circuits on the property of the Railway Company.

5. Liability and Risk

(a) The Licensee shall not in any way or at any time interfere with the safe passage of the Railway Company's trains; and shall indemnify and save harmless the Railway Company and other companies and facilities on its property from any and all loss or damage to property and injury to or death of persons, or any suits, claims, liability or demands in connection therewith, however caused, resulting directly or indirectly from the installation, maintenance, use, existence or removal of said construction, unless due to the sole negligence of the Railway Company.

(b) The Licensee assumes all risk of loss or damage to property of the Licensee, however caused, resulting directly or indirectly from the installation, maintenance, use, existence or removal of said construction, and hereby releases the Railway Company from all liability on account of such loss or damage, whether or not the negligence of the Railway Company contributed thereto in whole or in part.

6. Insurance

The Licensee agrees to maintain insurance in favor of the Railway Company covering the liability assumed by the Licensee in Paragraph (5) in amounts not less than $25,000 for each person and $50,000 for each accident covering personal injuries or deaths, and $10,000 for each accident, and total or aggregate limits of $25,000 for property damage. Said insurance to be in such form as to meet the approval of the Railway Company and placed with an insurance company which meets the approval of the Railway Company.

Notwithstanding any provision in this agreement contained, the agreement shall not become effective until the form of insurance and the company with which such insurance is placed shall have been approved by the Railway Company as above provided and shall remain in effect only during the time said insurance shall remain in effect.

7. Risk

The Licensee assumes all risk of loss or damage to property of the Licensee on the premises of the Railway Company, however caused, and hereby releases the Railway Company from all liability on account of such loss or damage.

8. Changes and Removal

The Licensee shall, at its sole expense, within .... days after receipt of written notice from the Railway Company, remove from the premises of the Railway Company said construction or make such changes therein, including relocation, as may be required by the Railway Company, if such removal, changes or relocation shall be needed for the better development or use of the property of the Railway Company, or if such removal, changes or relocation shall, in the judgment of the Railway Company, be needed to protect its requirements or contractural obligations.

9. Discontinuance

The Licensee shall, at its sole expense, upon discontinuance of use of said construction, promptly remove its property from the premises of the Railway Company and restore said premises, disturbed by said construction, to a condition satisfactory to the Railway Company, and upon the completion of such work this agreement shall terminate.

10. Cost of Changes

The Licensee failing to remove, change or relocate its construction within .... days after the expiration of notice given as provided in Section 8, the Railway Company, may, without further notice, remove, change or relocate the construction and render bills for the cost of such removal, change or relocation to the Licensee which bills the Licensee agrees to pay on or before the fifteenth day of the month next succeeding that in which such bill is rendered.

11. Taxes

The Licensee shall pay all taxes assessed upon said construction, or on account of the existence of said construction and shall indemnify the Railway Company from the payment of such taxes.

12. Failure to Exercise Rights Not to Constitute Waiver

The failure of Railway Company to exercise its rights hereunder upon the failure of Licensee to perform the convenants and conditions herein contained, shall not be construed as a waiver of the convenants or conditions herein contained, but only a waiver of the particular breach, and Railway Company may, at any time thereafter, upon the failure of Licensee to perform the convenants or conditions in this agreement on its part to be kept and performed, exercise rights as herein provided.

13. Execution Official Act Only

The parties executing this agreement do so only in their official capacity, and only to the extent that they may have been authorized so to do, and none of the convenants herein contained are to be held or construed as their individual acts, or acts for which they may be individually liable in any way. No warranty of title to any property is given hereunder.

14. Rentals

The Licensee shall pay to the Railway Company for the privileges herein granted as rent, an annual charge for the use of the Railway Company's property in accordance with the schedule of rental charges hereto attached and made a part hereof, marked Exhibit "B"—Schedule, said rental to be payable in advance on date of this agreement and on anniversary date thereof; such installations made subsequent to the date of this agremeent shall be prorated and adjusted for the period ending ....

15. Cancellation

The within license is given for a period of one (1) year and thereafter, from year to year, but at all times the same may be revoked by the Railway Company, or cancelled by the Licensee, upon thirty (30) days' previous notice of such intention.

16. Successors

This agreement shall inure to the benefit of and be binding upon the parties hereto, their successors and assigns.

In Witness Whereof, the parties hereto have executed this agreement in ...., the day and year first above written.

Witness: .... Company.

By ....

Witness: .... Licensee.

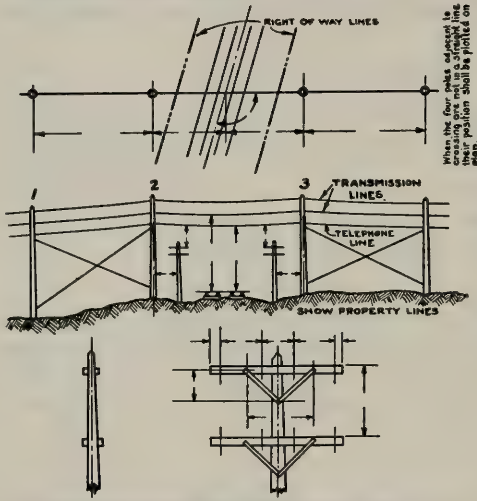
By ....

DATA TO BE INCORPORATED ON PLANS PREPARED BY APPLICANT FOR WIRE CROSSINGS OVER RAILROAD RIGHT OF WAY

____________________ 19____

NAME OF APPLICANT____________________

ADDRESS OF APPLICANT____________________



When the four poles adjacent to crossing are not in a straight line their position shall be plotted on plan.

Note:

Application to cross must be accompanied by copies of actual plan, to scale, showing location of crossing poles, guys, existing lines, etc.

LOCATION DATA

Distance and Direction of Crossing from Nearest Railroad

Mile Post, Monument or Center Line of Station__________

Railroad Operating Division__________

Valuation Station__________

County__________ State__________

CROSSING DATA

Voltage__________ Frequency__________

A.C. or D.C.__________ No. of Circuits__________

WIRES-No. of__________ Size of__________

Material__________

Solid or Stranded__________

Bare or Insulated__________

Hard or Soft Drawn__________

SAG in WIRES__________

Design Tension at Max. Load__________

Stringing Sag__________

Sag under Max. Load__________

Ultimate Unloaded Sag__________

CLAMP or TIE__________

Type__________

INSULATOR-Type__________

Material__________

Maker and Cat. No.__________

GUY INSULATOR-Type__________

Material__________

Maker and Cat. No.__________

TELEPHONE LINE__________

Wire-Material__________ Size__________

TEL. INSULATOR-Type__________

Material__________

Maker and Cat. No.__________

POLE TOP CONSTRUCTION SHOW AS ABOVE

DATA REQUIRED

Show Telephone Wire Attachments if any.

Size of Arms__________ Material__________

Size and Type of Brace__________

Pin Spacing__________

Size and Type of Pins__________

Type of Arm Separator__________

Grounding Connection__________ Material__________ Size__________

Aerial Ground Wire__________ Material__________ Size__________

POLES	Height Above Ground	DIA. AT		Depth of Holes
		Ground	Top	
No. 1				
No. 2				
No. 3				
No. 4				

Marking of Poles__________

Species of Timber__________

Size of Guy Wire__________ Material__________

Type of Guy Anchorage__________

Exhibit A.

Exhibit "B"—Schedule

SCHEDULE OF FEES AND RENTALS
FOR
ELECTRIC LIGHT, POWER SUPPLY AND TROLLEY WIRES CROSSING RAILWAYS

License Fees

Public Highways—Crossings confined entirely to the highway limits	No Charge
Private Right of Way and Property—Crossings not exceeding 1,000 volts	$10.00
Over 1,000 volts but not exceeding 7,500 volts	20.00
Over 7,500 volts	30.00

Where more than one voltage is involved the highest voltage shall govern the fee.

Annual Rentals

In computing the rental to be charged for any wire or cable crossing or a crossing containing both wires and cables, where more than one item is involved and the sum of the individual rentals specified is less than the largest minimum, the rental shall be the said largest minimum.

The minimum annual rental under any agreement where a rental is involved shall be $2.00.

Aerial Wires

Public Highways—Crossings wholly within the limits of public highways..No Rental

Private Right of Way and Property—Crossings not exceeding 200 ft. in length, annual rentals will be as follows:

(a)	Not exceeding 1,000 volts	per wire	$ 0.50
	Minimum for any one crossing		3.00
(b)	Over 1,000 volts but not exceeding 3,000 volts	per wire	1.00
	Minimum for any one crossing		6.00
(c)	Over 3,000 volts but not exceeding 7,500 volts	per wire	1.50
	Minimum for any one crossing		10.00
(d)	Over 7,500 volts	per wire	3.00
	Minimum for any one crossing		15.00

A proportionate additional rental calculated to the nearest dollar shall be made for any crossing in excess of 200 ft. in length.

Aerial Cables

Public Highways—Crossings wholly within the limits of public highways..No Rental

Private Right of Way and Property—Crossings not exceeding 200 ft. in length, annual rentals will be as follows:

(a)	Not exceeding 1,000 volts	per conductor	$ 0.05
	Minimum for any one crossing		3.00
(b)	Over 1,000 volts but not exceeding 3,000 volts	per cable	3.00
	Minimum charge for any one crossing		5.00
(c)	Over 3,000 volts but not exceeding 7,500 volts	per cable	4.00
	Minimum charge for any one crossing		7.00
(d)	Over 7,500 volts	per cable	6.00
	Minimum charge for any one crossing		10.00

A proportionate additional rental calculated to the nearest dollar shall be made for any crossing in excess of 200 ft. in length.

Underground Wires and Cables and Conduit For Electrical Conductors

Public Highways—Crossings wholly within the limits of public highways. . No Rental

Private Right of Way and Property—Crossings not exceeding 200 ft. in length, annual rentals will be as follows:

(a)	Not exceeding 1,000 volts	per conductor	$0.025
	Minimum for any one crossing		2.00
(b)	Over 1,000 volts but not exceeding 7,500 volts	per conductor	1.00
(c)	Over 7,500 volts	per conductor	2.00
(d)	Spare or unoccupied ducts or pipes	each	0.50
	When the duct shall be occupied in the future by a cable, the annual rental charge for the cable shall govern and the 50 cents charge shall cease.		
(e)	Ducts or pipes carrying conductors		No Rental

A proportionate additional rental calculated to the nearest dollar shall be made for any crossing in excess of 200 ft. in length.

Report of Committee 16—Economics of Railway Location and Operation

H. M. Stout, *Chairman,*
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E. Y. Allen
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J. A. Anderson
S. E. Armstrong
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W. D. Wiggins
H. W. Williams
S. L. Wonson
John S. Worley

Committee.

To the American Railway Engineering Association:

Your committee respectfully submits herewith its report on the following subjects:

1. Revision of Manual (Appendix A). Final report on II Power with recommendations of substitutions.

2. Methods for obtaining a more intensive use of existing railway facilities (Appendix B). Progress report.

3. Methods or formulas for the solution of special problems relating to more economical and efficient railway operation (Appendix C). This is a subject in series. The special subject considered this year is: (k) Economic relation between track structure and traffic to be handled. Progress report.

4. Methods for determining most economical train length, considering all factors entering into transportation costs, collaborating with Operating division (Appendix D). Final report, with recommendations for inclusion in the Manual.

5. Effect of volume of traffic on railway operating expenses, collaborating with Committee 22—Economics of Railway Labor. Progress in study—no report.

6. Effect of inland waterway transportation on the economics of railway operation (Appendix E).

(a) The Ohio river and tributaries.
(b) The New York barge canal.
(c) The proposed canal connecting Lake Erie with the Ohio river.

Progress report.

7. Effect of high-speed on railway operating expenses (Appendix F). Progress report.

8. Effect of rail lubrication on train operation, collaborating with Committee 5—Track (Appendix G). Progress report.

9. Economics of railway location and operation as affected by railway electrification (Appendix H). Progress report.

10. Compile operating data essential to establish units for making line and grade revisions to meet operating requirements (Appendix I). Final report with recommendations for inclusion in the Manual.

11. Effects of speeds in excess of 75 miles per hour on the economics of railway location (Appendix J). Progress report.

12. Grades and alinement through tunnels (Appendix K). Final report with recommendations for inclusion in the Manual.

13. Effect of highway transportation on the economics of railway operation. Progress in study—no report.

Bulletin 413, November, 1939.

Supplementing work on the assignments listed above, a subcommittee of Committee 16 has collaborated with a subcommittee of Committee 5—Track on Spirals for high-speed operation, a former assignment to this committee which was transferred by the Board of Direction to Committee 5 for further consideration. See the report of Committee 5—Track.

The Committee on Economics of Railway Location and Operation,
H. M. Stout, *Chairman.*

Appendix A

Revision of Manual

E. E. Kimball (chairman, subcommittee), J. A. Anderson, S. E. Armstrong, J. H. Dyer, J. L. Haugh, E. E. King, M. F. Mannion, F. H. McGuigan, Jr., L. K. Sillcox, H. W. Snyder, W. D. Wiggins.

Your committee presents below, in condensed form, the substance of the report on Power which was submitted as information at the convention last year. The report as now presented is submitted for adoption and publication in the Manual to replace the matter now appearing under the heading "II Power", on Manual pages 16–9 to 16–24, inclusive.

II. POWER

1940

The principal types of motive power used by railroads are steam, electric and oil (Diesel)-electric locomotives. The latter type also embraces gas-electric rail cars and turbo-electric locomotives.

In order to compare the operating advantages of different types of locomotives, or study the economic value of various locations and gradients, it is important that comparable methods be used for calculating the characteristics or speed tractive effort and horsepower curves of these locomotives.

The methods which have been developed for this purpose are based on the following general principles and consist of a number of forms or work sheets which are intended to take the place of formulas and also to serve a useful purpose in arranging the calculations in convenient form for ready reference and comparison.

GENERAL PRINCIPLES

Fundamentally the purpose of any locomotive is to furnish power to pull trains. The final output is a combination of speed and tractive effort which is usually referred to as the characteristics of the locomotive.

(a) *Horsepower.*—The power developed or exerted by a locomotive is generally measured in terms of horsepower (33,000 ft.-lb. of work per minute). It is equal to the product of the tractive effort in pounds times the speed in miles per hour divided by 375, or mathematically expressed

$$\text{Hp.} = \frac{\text{T.E.} \times \text{M.P.H.}}{375}$$

(b) *Tractive Effort.*—For the sake of uniformity in dealing with different types of motive power, tractive effort is defined as the force exerted at the driving axles to propel the locomotive.

In the case of steam locomotives it is generally necessary to be more specific because the tractive effort at the drivers is based on the cylinder or indicated horsepower after deductions have been made for the mechanical losses in the engine. It is therefore customary to designate the tractive effort as cylinder (or indicated) tractive effort and driver tractive effort, as the case might be, instead of tractive effort alone.

(c) *Locomotive Capacity.*—Theoretically, the capacity of any locomotive is limited in two ways: First by the amount of power it can use, and second by the amount of power it can develop. The first limit is set by the adhesion between the drivers and the rails and hence is known as the adhesion limit. The second limit is set by the amount of power available on the locomotive which is usually referred to as the horsepower capacity of the locomotive.

(d) *Maximum Tractive Effort.*—The adhesion which determines the maximum tractive effort of a locomotive depends upon rail and weather conditions. Under poor rail conditions it may amount to less than 5 percent of the weight on drivers, whereas under exceptionally good conditions it may exceed 40 percent of the weight on drivers. Poor rail conditions can be improved by the use of sand so that in practice it is generally assumed that maximum tractive efforts equal to 25 to 30 percent of the weight on drivers can normally be expected.

(e) *Adhesion Limit.*—The horsepower which is fixed by the adhesion limit is therefore proportional to the product of the maximum tractive effort times the speed and hence can be represented by a straight line OA in Figs. 1 and 2.

(f) *Available Horsepower.*—The horsepower which is available on a locomotive, depends upon the source of power and upon the type and design of locomotive.

In the case of steam locomotives all the power is developed on the locomotive and therefore is limited to the capacity of the boiler which can be represented by a horizontal line B′C′ or BC in Fig. 1.

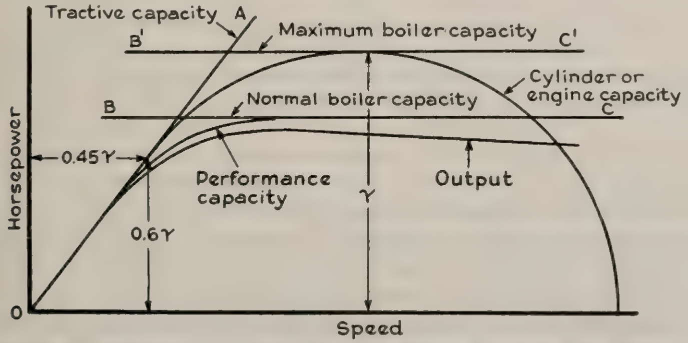

Fig. 1—Diagram Illustrating Tractive Capacity—Boiler Capacity and Engine Capacity of Steam Locomotives.

In the case of electric locomotives power is received from an outside source which is assumed to have unlimited capacity, hence the theoretical capacity of an electric locomotive depends only on its adhesion limit.

(g) *Conversion of Power.*—All available forms of power must be converted into mechanical power for application to the driving axles, therefore in practice the theoretical capacity of any locomotive is modified by the characteristics of the power converting equipment.

In the case of steam locomotives the cylinder or engine capacity can be approximately represented by a curve resembling a circle as shown in Fig. 1. The capacity of an electric locomotive is limited by the capacity of the traction motors and can be represented by typical characteristic curves as shown in Fig. 2. The capacities of oil-electric or turbo-electric locomotives are limited by the capacity of the engine or boiler and the capacity of the electrical equipment.

For a balanced design in the case of steam locomotives the engine should be able to produce as much power in starting as the locomotive can use and also utilize the full capacity of the boiler when producing maximum horsepower. In other words the circle or curve representing engine capacity should be tangent to both OA and B′C′ as shown in Fig. 1.

In the case of electric and oil-electric locomotives the electrical equipment is designed with large overload capacities in order to meet heavy demands for power.

(h) *Operation.*—The operation of electric and oil-electric locomotives can be controlled more or less automatically, whereas the operation of steam locomotives is largely left to the judgment of the operator. For this reason and in order to obtain economical results it is customary to base the service performance of steam locomotives on approximately three-fourths of their maximum capacity as shown in Fig. 1.

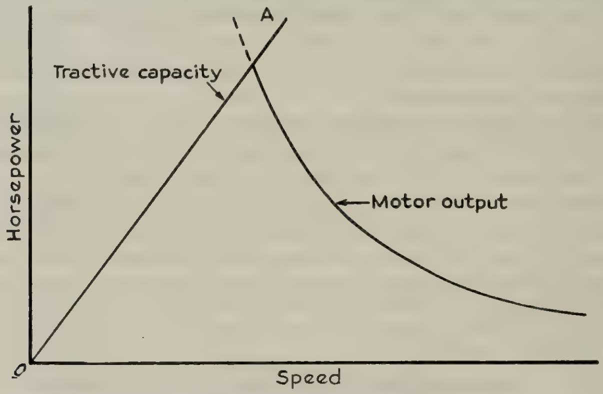

Fig. 2.—Diagram Illustrating Tractive Capacity and Motor Characteristics Electric Locomotives.

The effect of this reduction in capacity is equivalent to discounting the maximum or theoretical performance about 10 percent, which is the allowance usually recommended in estimates of the performance of electric and oil-electric locomotives.

(i) *Miscellaneous.*—The fundamental elements of locomotive design which are essential for successful operation and which concern locating and transportation engineers are weight, tracking qualities and capacity. These elements are more or less interrelated because they all depend upon the wheel arrangement or locomotive classification, but they may be varied within limits to suit different services or different types of motive power.

Two methods for classifying locomotives by their wheel arrangements have been adopted; one is used for steam locomotives and the other for electric and oil-electric locomotives. The reason for the two methods is to avoid confusion in distinguishing between driving and non-driving axles in the case of electric drive because the mechanical construction of these locomotives varies over a wider range than is practical for steam locomotives.

STEAM LOCOMOTIVES

Locomotive Classification

Since the weight, tracking qualities and capacity of steam locomotives depend upon the wheel arrangement, one of the first steps in the study of motive power is to point out some of these relations.

Weight.—In most cases the maximum allowable weight per axle of locomotives based on the character of roadbed, track and track structures can be tentatively assumed. The weight of the locomotive will then depend upon the number of axles employed.

Capacity.—Likewise the horsepower capacity of the locomotive will depend upon its weight and therefore on the number of axles.

Tracking Qualities.—The tracking qualities of the locomotive will depend upon whatever provisions are required for guiding it around curves at the speeds it is expected to run. This is accomplished by leading and trailing trucks equipped with one or more pairs of idle wheels.

Thus it is important to classify locomotives in accordance with their wheel arrangement.

The Whyte method for classifying steam locomotives is a system which is used to designate the number of trucks and the arrangement of wheels under a locomotive. Thus, 2–8–2 refers to locomotives which are supported on three trucks, the first truck or the one nearest the cylinders is considered the guiding truck and contains two wheels, the second is the driving or rigid truck composed of eight driving wheels and the third is the trailing truck which contains two wheels.

Articulated locomotives have two sets of drivers and are supported on four trucks and classified as follows: 2–6+6–0, 2–6+6–2, etc. The plus sign indicates the articulation between the two driving trucks.

Switching locomotives are classed as follows: 0–6–0, 0–8–0, 0–10–0, which indicates that they have no guiding or trailing trucks and therefore all of the weight is on drivers.

The percentage of weight which is carried on drivers for other classes of locomotives depends upon the number of guiding and trailing wheels, as indicated in Table I. For example, in the case of 4–6–4 locomotives only 52 to 57 percent of the weight of the engine is carried on the drivers.

Table of Horsepower Capacities

The object of Table I is to enable locating and operating engineers to determine approximately the horsepower capacities which can be obtained from different classes of modern steam locomotives and which can be used as a basis for comparison or for estimating locomotive performance. The horsepowers given in the table are based on three-fourths of the maximum horsepowers obtainable in tests and only apply to locomotives which reasonably satisfy this condition.

When considering actual locomotives the horsepowers used for estimating performances should be based on three-fourths of the maximum capacity as determined from tests or design experience.

Some of the older classes of locomotives are not listed in the table because they are being superseded and the horsepowers derived would not apply. New classes when developed can be added, consequently it will be necessary to revise the table from time to time in order to keep pace with new developments in design and construction.

The approximate horsepower capacities of new classes of locomotives based on their wheel arrangement and present day experience, can be obtained from the table if the weight on drivers and the weight of engine are known. For example, if the estimated weight on drivers for a proposed 4–8–6 locomotive is 135 tons and amounts to 50 percent

TABLE 1

Used for Obtaining Normal H.P. Capacities (75% of Maximum) of Typical Steam Locomotives From the Weight of Engine and Weight on Drivers

Based on Coal Fired Locomotives Using Superheated Steam

Weight on Drivers Per cent		HP Per Ton on Drivers	Types of Locomotives Available			Weight on Drivers Per cent		HP Per Ton on Drivers	Types of Locomotives Available		
Wt. of Eng.	Wt. of Eng. & Tender					Wt. of Eng.	Wt. of Eng. & Tender				
41						71	40.8	28.2	2-10-4	2-8-2	
42						72	41.4	27.8	2-10-4	2-8-2	
43	24.0	40.0	4-4-4			73	42.0	27.4		2-8-2	
44	24.6	39.6	4-4-4			74	42.6	26.9	2-10-2	2-8-2	
45	25.2	39.2	4-4-4			75	43.2	26.5	2-10-2	2-8-2	
46	25.8	38.7	4-4-4			76	43.8	26.1	2-10-2	2-8-2	
47	26.4	38.3	4-4-4			77	44.4	25.7	2-10-2	2-8-2	
48	27.0	37.9				78	45.0	25.3	2-10-2	2-8-2	
49	27.6	37.5				79	45.6	24.8	2-10-2	2-8-2	
50	28.2	37.1	4-4-2			80	46.2	24.4	2-10-2		
51	28.8	36.6	4-4-2			81	46.8	24.0	2-10-2		
52	29.4	36.2	4-4-2	4-6-4		82	47.4	23.6	2-10-2		
53	30.0	35.8	4-4-2	4-6-4		83	48.0	23.2	2-10-2		
54	30.6	35.4	4-4-2	4-6-4		84	48.6	22.7	2-10-2		
55	31.2	34.9	4-4-2	4-6-4		85	49.2	22.3			0-10-2
56	31.8	34.5	4-4-2	4-6-4		86	49.8	21.9			
57	32.4	34.1	4-4-2	4-6-4	4-8-4	87	50.4	21.5		2-8-0	
58	33.0	33.7	4-6-2		4-8-4	88	51.0	21.1		2-8-0	
59	33.6	33.3	4-6-2		4-8-4	89	51.6	20.6		2-8-0	
60	34.2	32.8	4-6-2	2-8-4	4-8-4	90	52.2	20.2	2-10-0	2-8-0	
61	34.8	32.4	4-6-2	2-8-4	4-8-4	91	52.8	19.8	2-10-0	2-8-0	
62	35.4	32.0	4-6-2	2-8-4	4-8-4	92	53.4	19.4	2-10-0	2-8-0	
63	36.0	31.6	4-6-2	2-8-4	4-8-4	93	54.0	18.9	2-10-0	2-8-0	
64	36.6	31.2	4-6-2	2-8-4	4-8-4	94	54.6	18.5			
65	37.2	30.7	4-6-2	2-8-4	4-8-2	95	55.2	18.1			
66	37.8	30.3	2-10-4	2-8-4	4-8-2	96	55.8	17.7			
67	38.4	29.9	2-10-4	2-8-4	4-8-2	97	56.4	17.2			
68	39.0	29.5	2-10-4		4-8-2	98	57.0	16.8			
69	39.6	29.1	2-10-4	2-8-2	4-8-2	99	57.6	16.4			
70	40.2	28.6	2-10-4	2-8-2	4-8-2	100	58.2	16.0			

4 Cylinder Articulated Locomotives

67					79	49.2	22.3	2-8+8-4	
68	44.6	25.6	4-6+6-4		80	49.7	22.0	2-8+8-4	
69	45.0	25.3	4-6+6-4	2-6+6-4	81	50.1	21.7	2-8+8-4	
70	45.4	25.0	4-6+6-4	2-6+6-4	82	50.5	21.4	2-8+8-4	
71	45.8	24.7		2-6+6-4	83	51.0	21.1	2-8+8-4	2-6+6-2
72	46.2	24.4		2-6+6-4	84	51.4	20.8	2-8+8-4	
73	46.7	24.1		2-6+6-4	85	51.8	20.5	2-8+8-4	
74	47.1	23.8		2-6+6-4	86	52.2	20.2	2-8+8-4	2-8+8-2
75	47.5	23.5		2-6+6-4	87	52.6	19.9		2-8+8-2
76	48.0	23.2		2-6+6-4	88	53.0	19.6		2-8+8-2
77	48.4	22.9	2-8+8-4		89	53.4	19.3		2-8+8-2
78	48.8	22.6	2-8+8-4		90	53.9	19.0		2-8+8-2

of the weight of the engine, then the normal capacity which can be expected for the locomotive may be determined by referring to the table for the horsepower capacity per ton on drivers (37.1) which applies to locomotives having 50 percent of their weight (exclusive of the tender) on drivers. The normal capacity of the locomotive will therefore be about 5,000 hp. and the maximum capacity 4/3 × 5,000 or 6,675 hp.

Weight of Tenders.—The purpose of the second column of the table is to obtain the approximate weight of engine and tender for use in general studies. Thus, the weight of tenders can be estimated and later adjusted to meet the requirements of any particular service when necessary.

Typical Characteristics of Steam Locomotives

In order to simplify the calculation of fuel and water consumptions, it is advantageous to base performance estimates on typical characteristic curves assuming a uniform rate of firing and a constant rate of evaporation.

Forms A and B are sample work sheets developed on this basis for computing and tabulating the speed-tractive effort curves of typical steam locomotives using superheated steam.

Form A is the simpler one and is intended to be used when design data are not available. It is based on an adhesion factor of 4 (25 percent of the weight on drivers), which is equivalent to a tractive effort of 500 lb. per ton on drivers.

In other words this form is intended to be used when the tractive effort obtained by the formula

$$\frac{0.85 \times d^2 \times S \times P}{D} = \tfrac{1}{4} \text{ of the weight on drivers.}$$

Where $d =$ diameter of pistons in inches
$S =$ length of stroke in inches
$P =$ boiler pressure in lb. per sq. inch
$D =$ diameter of drivers in inches

The driver tractive efforts corresponding to V_1 and multiples of V_1 shown in Col. (c) Form A are based on cylinder tractive efforts less 20 lb. per ton on drivers in order to allow for the mechanical losses in the engine.

The speed in miles per hour corresponding to V_1 depends upon the horsepower capacity of the locomotive and is obtained as shown in Item 9. (equals 0.396 × the normal horsepower per ton on drivers).

Form B is a more general work sheet which is intended to be used when dealing with specific locomotives or when design data are available. The method is the same as in Form A except that it is necessary to make provision for adjustments which are required on account of variations in actual designs. The cylinder tractive efforts, Col. (d), are based on the adjusted or effective weight on drivers, and the engine losses, Col. (e), on the actual weight on drivers, Item 2. Space is also provided on the form opposite Item 8 to indicate the basis used for determining the horsepower capacity of the locomotive.

The cylinder tractive efforts per ton on drivers, Col. (c), are obtained from the cylinder horsepowers, Col. (g), as explained in the mathematical demonstration on page 67, which also shows the derivation of the constant 0.396 that appears in Item 9, Forms A and B.

A sample application of Form B to the following locomotive data is shown on page 66 to illustrate the method.

FORM A

FORM FOR CALCULATING
THE TRACTIVE EFFORT AND HORSEPOWER OUTPUT
OF TYPICAL STEAM LOCOMOTIVES
USING SUPERHEATED STEAM

____________________ RAILROAD

Item

1. Type (Wheel Arrangement)____________________
2. Weight on Drivers (Tons)____________________
3. Weight of Engine ____________________
4. Weight of Tender ____________________
5. Total Weight ____________________

6. Ratio Item (2)/Item (3)____________________

7. HP Per Ton on Drivers From Table 2 = K __________ K' __________
8. HP Capacity of Loco. Item (2) x Item (7)____________________
9. Basic Speed MPH = V_1 = .396 x K ____________________

Speed		Driver Tractive Effort		
V	MPH	Per Ton on Drivers	Total	
(a)	(b)	(c)	(d)	
0	0	500		
1.00xV_1		480		
1.25 "		473		
1.50 "		453		
1.75 "		427		
2.00 "		397		
2.25 "		369		
2.50 "		341		
2.75 "		314		
3.00 "		290		
3.50 "		250		
4.00 "		217		
4.50 "		190		
5.00 "		169		
6.00 "		138		
7.00 "		(115)		

With Booster

0		500		
1.00xV_1'		480		
1.25 "		473		
1.50 "		453		
1.75 "		427		
2.00 "		397		

Col. (b) = Col. (a) x Item (9)   Col. (d) = Col. (c) x Item (2)

For Locomotives using Boosters add weight on Booster Axle to weight on Drivers, then K' equals Item (8)/Item (2) including weight on Booster Axle.

FORM B

FORM FOR CALCULATING
THE TRACTIVE EFFORT AND HORSEPOWER OUTPUT
OF TYPICAL STEAM LOCOMOTIVES
USING SUPERHEATED STEAM

________________ RAILROAD

Item
1. Type (Wheel Arrangement)________________

	Actual	*Adjusted	(a) Booster
2. Weight on Drivers (Tons)			
3. Weight of Engine			
4. Weight of Tender			
5. Total Weight			
6. Ratio Item (2)/Item (3)			

	Based on Table I	Based on Design	See Note
7. HP per Ton on Drivers = K		ø	K'
8. HP Capacity of Locomotive			
9. Basic Speed MPH = V_1 = .396 x K			V_1'

Speed		Cylinder Tractive Effort		Engine Losses	Driver Tract.	Cylinder HP		
V	MPH	Per Ton on Drivers	Total	20 Lb/Ton Act.Wt. on Drivers	Effort Col(d)-Col(e)	Per Ton on Drivers Adj.Wt.	Total	Driver HP Total
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)
0	0	500		0		0	0	0
1.00 x V_1		500				.528 x K		
1.25 "		493				.649 "		
1.50 "		473				.748 "		
1.75 "		447				.824 "		
2.00 "		417				.880 "		
2.25 "		389				.921 "		
2.50 "		361				.948 "		
2.75 "		334				.967 "		
3.00 "		310				.980 "		
3.50 "		270				.993 "		
4.00 "		237				.997 "		
4.50 "		210				.999 "		
5.00 "		189				1.000 "		
6.00 "		158				1.000 "		
7.00 "		(135)						

With Booster

0		500						
1.00 x V_1'		500						
1.25 "		493						
1.50 "		473						
1.75 "		447						
2.00 "		417						

*Adjusted weight on drivers (tons) = Rated tractive effort/500

øHP = K = Item (8)/Adjusted wt. on drivers

Col.(d) = Col.(c) x Item (2) Adjusted

Col.(f) = Col.(d) - Col.(e)

Col.(h) = Col.(g) x Item (2) Adjusted

Col.(i) = Col.(b) x Col.(f)/375

TE corresponding to 7xV_1 may be limited by cylinder capacity

(a) Note for locomotives with boosters weight on drivers equals rated tractive effort incl. booster/500. Determine K' and V_1'as above.

FORM B

FORM FOR CALCULATING THE TRACTIVE EFFORT AND HORSEPOWER OUTPUT OF TYPICAL STEAM LOCOMOTIVES USING SUPERHEATED STEAM

SAMPLE RAILROAD

Item
1. Type (Wheel Arrangement) 4-6-4

Item		Actual	*Adjusted	(a) Booster
2.	Weight on Drivers (Tons)	97.5	88.0	108.0
3.	Weight of Engine	185.0		
4.	Weight of Tender	165.0		
5.	Total Weight	350.0		
6.	Ratio Item (2)/Item (3)			

Item		Based on Table 1	Based on Design	See Note
7.	HP per Ton on Drivers = K	36.0	∅ 39.3	K' 32.4
8.	HP Capacity of Locomotive	3500		
9.	Basic Speed MPH = V_1 = .396 x K		15.75	V_1'

Speed		Cylinder Tractive Effort		Engine Losses 20 Lb/Ton Act.Wt. on Drivers	Driver Tract. Effort Col(d)-Col(e)	Cylinder HP		Driver HP Total
V	MPH	Per Ton on Drivers	Total			Per Ton on Drivers Adj.Wt.	Total	
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)
0	0	500	44,000	0	44,000	0	0	0
1.00 x V_1	15.75	500	44,000	1950	42,050	.528 x K	1848	1766
1.25 "	19.70	493	43,300	1950	41,350	.649 "	2272	2171
1.50 "	23.63	473	41,600	1950	39,650	.748 "	2618	2500
1.75 "	27.56	447	39,350	1950	37,400	.824 "	2884	2750
2.00 "	31.50	417	36,700	1950	34,750	.880 "	3080	2920
2.25 "	35.44	389	34,250	1950	32,300	.921 "	3224	3055
2.50 "	39.38	361	31,800	1950	29,850	.948 "	3318	3135
2.75 "	43.32	334	29,400	1950	27,450	.967 "	3385	3175
3.00 "	47.25	310	27,300	1950	25,350	.980 "	3430	3195
3.50 "	55.13	270	23,800	1950	21,850	.993 "	3476	3205
4.00 "	63.00	237	20,900	1950	18,950	.997 "	3490	3185
4.50 "	70.88	210	18,500	1950	16,550	.999 "	3497	3125
5.00 "	78.75	189	16,650	1950	14,700	1.000 "	3500	3085
6.00 "	94.50	158	13,900	1950	11,950	1.000 "	3500	3010
7.00 "		(135)						

With Booster

0	0	500	54,000	0	54,000			
1.00 x V_1'	12.84	500	54,000	2160	51,840			
1.25 "	16.05	493	53,200	2160	51,040			
1.50 "	19.26	473	51,100	2160	48,940			
1.75 "		447	48,300	2160	46,140			
2.00 "	25.68	417	45,000	2160	42,840			

*Adjusted weight on drivers (tons) = Rated tractive effort/500

∅HP = K = Item (8)/Adjusted wt. on drivers

Col.(d) = Col.(c) x Item (2) Adjusted

Col.(f) = Col.(d) - Col.(e)

Col.(h) = Col.(g) x Item (2) Adjusted

Col.(i) = Col.(b) x Col.(f)/ 375

TE corresponding to 7xV_1 may be limited by cylinder capacity

(a) Note for locomotives with boosters weight on drivers equals rated tractive effort incl. booster/500. Determine K' and V_1'as above.

I. hp. per ton on drivers $= K\left(1 - e^{-0.75(U)^{3/2}}\right)$

Where K = normal hp. capacity per ton on drivers

$e = 2.718 +$ (base of Naperian logarithms)

$U = \frac{V}{V_1}$

V and V_1 = speeds in miles per hour

When $V = V_1$ I. hp. per ton on drivers $= K(1 - e^{-0.75})$

$= K(1 - 0.472)$

$= 0.528K$

Also, when $V = V_1$ I. hp. per ton on drivers $= \frac{0.25 \times 2{,}000 \times V_1}{375} = \frac{500\ V_1}{375}$

or $\frac{500\ V_1}{375} = 0.528K$

hence $V_1 = 0.396K$ (See item (9), Forms A and B

Values in column (c), Form B, are found as follows.

When $V = 2V_1$ I. hp. per ton on drivers $= K\left(1 - e^{-0.75(2)^{3/2}}\right)$

$= K(1 - e^{-2.121})$

$= 0.880\ K$

and the tractive effort per ton on drivers $= \frac{0.880K \times 375}{2 \times V_1}$

$= \frac{.880\ K \times 375}{2 \times 0.396K}$

$= 417$ lb

Typical Design Data Pertaining to Steam Locomotives

Type	4–6–4
Weight on drivers	195,000 lb.
Weight of engine	371,000 lb.
Weight of tender	330,000 lb.
Total weight	701,000 lb.
Boiler pressure per sq. in.	285 lb.
Diameter of drivers	80 in.
Cylinders, diameter times stroke	22 × 30 in.
Tractive effort engine	44,000 lb.
Tractive effort, including booster	54,000 lb.

Tractive effort engine divided by weight on drivers, 44,000/195,000 equals 0.226, or less than 0.25, hence use Form B.

Adjusted weight on drivers equals 44,000/500, or 88 tons.

The horsepower capacity of the locomotive based on design is unknown, therefore, using the ratio of Item (2) to Item (3), 0.525, and referring to Table I the corresponding horsepower per ton on drivers is found to be 36, as shown for Item 7 or 3,500 hp. total, Item 8.

The horsepower per ton of adjusted weight on drivers becomes 3,500/88, or 39.8 and V_1 equals 0.396 × 39.8, or 15.75 mph.

ELECTRIC LOCOMOTIVES

Systems of Electrification

There are two general systems of electrification, namely, the direct-current and the alternating-current systems.

Types of Electric Locomotives

In all, there are four distinct types of electric locomotives: (a) Direct-current locomotives, (b) single-phase alternating-current locomotives, (c) split-phase induction-motor locomotives and (d) single-phase motor-generator locomotives. The last three types have been developed for the alternating-current system. The same basic principles apply to all four types, but their characteristics are inherently different which makes it necessary to provide different work sheets for calculating their speed-tractive effort curves.

Difference Between Steam and Electric Locomotives

Locomotive Capacity.—From a performance standpoint the chief difference between steam and electric locomotives is due to the fact that the output of steam locomotives is limited by the capacity of the boiler to supply steam, whereas electric locomotives draw their power from an outside source which has a relatively unlimited capacity. Theoretically, the capacity of an electric locomotive is therefore only limited by the amount of power which can be used without slipping the drivers and by the capacity of the electrical equipment.

Adhesion Limit.—On account of the uniform tractive effort and overload capacities of electric motors, the adhesion limit for electric locomotives is higher than it is for steam locomotives, but in most instances it is assumed the same as for steam locomotives, namely, (25 percent of the weight on drivers). The equipment, however, is generally designed with sufficient overload capacity to develop tractive efforts up to or exceeding 30 percent of the weight on drivers when rail conditions permit.

Locomotive Classifications.—The mechanical design and construction of steam and electric locomotives are naturally different because the methods used for applying power are different. For this reason the wheel arrangements in the case of electric locomotives are more numerous and varied than in the case of steam locomotives. In fact, it is necessary to employ a different method from the one adopted for classifying steam locomotives in order to identify the driving from non-driving axles.

In the electric system, letters are used to indicate the number of driving axles the first, second, third, etc. letters of the alphabet A, B, C, etc. indicate one, two, three driving axles and numerals represent idle axles. Thus 2–D–2 indicates two guiding axles, four driving axles and two trailing axles, and corresponds to 4–8–4 in the steam classification.

It is possible, however, to mount a motor on one of the axles of the guiding and trailing trucks without altering the wheel arrangement. According to the electric system, the locomotive would be classed a 1A–D–A1, which denotes three trucks and gives the location of all the drivers.

Where the electric system is used, the name plate is stamped with the wheel arrangement followed by the total weight of the locomotive and weight on drivers in thousands of pounds and by the number and make of motors. Sometimes an E or a D is inserted to indicate electric or Diesel locomotive.

Horsepower Rating of Electric Locomotives.—The horsepower rating of electric locomotives is an arbitrary rating which is determined by the heating of the motors in accordance with rules prescribed by the American Institute of Electrical Engineers. In actual cases it is customary for the manufactures to furnish characteristics of their locomotives and to specify the speeds and tractive efforts corresponding to the one-hour and continuous ratings.

In preliminary studies for the purpose of comparing performances of steam and electric locomotives it is often necessary to calculate the typical characteristic curves of electric locomotives before their ratings are established. Since it is impractical to prepare a table similar to Table I, showing the horsepower corresponding to various wheel arrangements for electric locomotives, the usual procedure in these cases is to calculate the characteristic curves of the steam locomotive first, establish its performance and then determine the characteristics of electric locomotives which will duplicate or better the steam performance.

Typical Speed-Tractive Effort Curves of Electric Locomotives

For this purpose typical speed tractive effort curves of direct-current and single-phase alternating-current locomotives can be calculated by the following empirical equations.

DIRECT CURRENT LOCOMOTIVES

$$*\frac{T'}{T''}=\left(\frac{V''}{V'}\right)^{3} \text{ or } \frac{V'}{V''}=\left(\frac{T''}{T'}\right)^{1/3}, \text{ or } \frac{V'}{V''}=\left(\frac{Hp.''}{Hp.'}\right)^{1/2}$$

That is, the tractive efforts of direct-current locomotives are approximately inversely proportional to the cube of the speeds.

SINGLE PHASE ALTERNATING CURRENT LOCOMOTIVES

$$\frac{T'}{T''}=\left(\frac{V''}{V'}\right)^{5/3} \text{ or } \frac{V'}{V''}=\left(\frac{T''}{T'}\right)^{3/5}, \text{ or } \frac{V'}{V''}=\left(\frac{Hp.''}{Hp.'}\right)^{3/2}$$

In other words, the tractive efforts of single-phase alternating-current locomotives, based on constant voltage, are approximately inversely proportional to the five-thirds power of the speed. Thus if the tractive effort corresponding to a given speed is known then the tractive effort corresponding to any other speed can be calculated by substituting in the above equations.

Forms C and D are sample work sheets, based on these formulas, designed to facilitate the calculation of speed-tractive effort and horsepower output of direct-current and single-phase alternating-current locomotives as well as the kilowatt output of substations. Form C covers direct-current locomotives and follows as near as possible along the same lines as Form B for steam locomotives.

The locomotive manufacturers usually base the hourly and continuous ratings of direct-current locomotives on full substation voltage, but for performance estimates it is customary to use the average trolley voltage which is assumed to be 90 percent of the substation voltage, consequently when substituting in the formula to find V_1 use 90 percent of the rated speed.

For example, if the speed corresponding to the rated tractive effort (say 160 lb. per ton on drivers) is 30 miles per hour, then the speed corresponding to 500 lb. per ton on drivers would be based on 90 percent of 30, or 27 mph., and obtained as follows:

$$\frac{V_1}{27}=\left(\frac{160}{500}\right)^{1/3} \text{ or } V_1=27\times(0.32)^{1/3}=27\times 0.684=18.5 \text{ mph.}$$

When V_1 is obtained, then the remainder of the form can be filled out assuming the weight on drivers is known.

To obtain higher tractive efforts at high speed it is customary to provide direct-current locomotives with two or more high-speed or shunted-field positions on the controller. In the highest speed position the speeds are usually assumed to be 20 percent higher for the same tractive effort than in the full-field position.

During acceleration it is necessary to limit the amount of power which is supplied the locomotive in order to avoid slipping the drivers. This is accomplished in the case of direct-current locomotives by inserting resistances in series with the motors, which causes considerable loss in power until the resistances can be cut out. The table at the bottom of Form C is for the purpose of estimating the excess power supplied by the substations during acceleration based on a coefficient of adhesion of 25 percent of the weight on drivers and covers three types of control. The three-speed control is only applicable when the number of motors per locomotive is divisible by 6.

Form D differs from Form C because of inherent differences in characteristics.

In the case of single-phase alternating-current locomotives the power input to the motors is controlled by means of variable-voltage taps on the transformer. On account

FORM C

FORM FOR CALCULATING
THE TRACTIVE EFFORT AND HORSEPOWER OUTPUT
OF TYPICAL ELECTRIC LOCOMOTIVES
DIRECT CURRENT

________________________RAILROAD

ITEM

1. Type (Wheel Arrangement)________________________
2. Weight on Drivers (Tons)________________________
3. Weight of Locomotive Total________________________
4. Number of Motors________________________

Locomotive Ratings	1-Hour	Continuous
5. Horsepower		
6. Speed (90% voltage)		
7. Tractive Effort		

Speed		Driver Tractive Effort		Locomotive Output		Substation Output	
V	Miles per Hour	Lbs per Ton on Drivers	Total	HP per Ton on Drivers	Total	KW per Ton on Drivers	Total
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
0	0			0	0	★	--
.94 x V_1		600		1.504 x V_1		1.460 x V_1	
1.00 "		500		1.333 "		1.270 "	
1.10 "		376		1.103 "		1.023 "	
1.20 "		289		.925 "		.844 "	
1.30 "		228		.790 "		.708 "	
1.40 "		182		.680 "		.605 "	
1.50 "		148		.592 "		.521 "	
1.60 "		122		.521 "		.457 "	
1.80 "		86		.413 "		.361 "	
2.00 "		63		.336 "		.295 "	
2.20 "		47		.276 "		.247 "	
2.40 "		36		.232 "		.213 "	
2.60 "		28		.194 "		.187 "	

Shunted Field

1.32 x V_1		376		1.324 x V_1		1.250 x V_1	
1.44 "		289		1.110 "		1.031 "	
1.56 "		228		.948 "		.866 "	
1.68 "		182		.816 "		.734 "	
1.80 "		148		.710 "		.632 "	
1.92 "		122		.625 "		.552 "	
2.16 "		86		.496 "		.435 "	
2.40 "		63		.403 "		.352 "	
2.64 "		47		.331 "		.291 "	

★Substation Output During Acceleration

Rheostatic		Series Parallel		Three Speed	
Speed	KW Output	Speed	KW Output	Speed	KW Output
From 0 to 1.0V_1	1.270 x V_1	From 0 to 1/2V_1	.612 x V_1	From 0 to 1/3V_1	.404 x V_1
		" 1/2V " 1.0V_1	1.270 "	" 1/3V_1 " 2/3V_1	.833 "
				" 2/3V_1 " 1.0V_1	1.270 "

FORM D

FORM FOR CALCULATING
THE TRACTIVE EFFORT AND HORSEPOWER OUTPUT
OF TYPICAL ELECTRIC LOCOMOTIVES
SINGLE PHASE ALTERNATING CURRENT

____________________ RAILROAD

ITEM

1. Type (Wheel Arrangement)____________________
2. Weight on Drivers (Tons)____________________
3. Weight of Locomotive Total____________________
4. Number of Motors____________________

Locomotive Ratings	1-Hour	Continuous
5. Horsepower		
6. Speed		
7. Tractive Effort		

Speed		Driver Tractive Effort		Locomotive Output		Substation Output	
V	Miles per Hour	Lbs per Ton on Drivers	Total ♣	HP per Ton on Drivers	Total	KW per Ton on Drivers	Total ★
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
0	0	500		0	0	0	0
1.00 x V_1		500		1.333 x V_1		1.333 x V_1	
1.10 "		426		1.250 "		1.250 "	
1.20 "		369		1.181 "		1.181 "	
1.30 "		323		1.120 "		1.120 "	
1.40 "		285		1.065 "		1.065 "	
1.50 "		254		1.016 "		1.016 "	
1.60 "		228		.973 "		.973 "	
1.80 "		188		.902 "		.902 "	
2.00 "		157		.837 "		.837 "	
2.20 "		135		.792 "		.792 "	
2.40 "		116		.742 "		.742 "	
2.60 "		102		.707 "		.707 "	
2.80 "		90		.671 "		.671 "	
3.00 "		80		.640 "		.640 "	

Supplementary Characteristic Curves

♣Driver Tractive Effort	Miles per Hour				KW Substation Output				
	V'	V"			Col★	V'	V"		
CONSTANT OUTPUT									
MPH									
TE									

of this feature it is not necessary to insert resistances in series with the motors when starting, which is the practice in the case of direct-current motors. Also a number of overvoltage taps are provided for high-speed operation, so that it is customary to assume constant horsepower output over a wide range in speed—from 60 percent speed to maximum speed when rating the locomotive. Also on account of these features, it is not necessary to adjust the speed for average trolley voltage.

The horsepower rating of single-phase alternating-current locomotives is usually based on 60 percent of the maximum speed. Given this rating, the speed in miles per hour corresponding to V_1 can be obtained by substituting in the formula,

$$\frac{V_1}{V'}=\left(\frac{T'}{T_1}\right)^{3/5}$$

However, it is much simpler to reduce the rated tractive effort to pounds per ton on drivers and refer to Form D for the corresponding speed. Thus, if the tractive effort corresponding to 60 mph. is 170 lb. per ton on drivers, then the speed obtained from the form will be between 1.8 and 2.0 $\times$ V_1, say, 1.92 $\times$ V_1, then 60 mph. $=$ 1.92 $\times$ V_1, or V_1 equals 31.2 miles per hour.

Supplementary characteristic curves can be calculated for other taps on the transformer, but when the locomotive is operated above 60 percent of its maximum rated speed, it is customary to base the performance on constant output in order to simplify the computations. In practice, it is possible for the engineman to overload the locomotive by operating on the high points of the controller, as can readily be seen by plotting one or two supplementary curves.

Space is provided at the bottom of Form D for tabulating the speed tractive effort characteristics based on constant output.

Weights of Electric Locomotives.—For estimating purposes it can generally be assumed that the weights of electric locomotives are comparable to the weights of steam locomotives (less tender) which are designed for the same service. That is, if design data are not available, the weight of electric locomotives can be assumed the same as for steam locomotives for determining the weight of train and calculating the typical speed-tractive effort curves for electric locomotives.

However the weight on drivers for electric locomotives will generally be more than for steam locomotives because electric locomotives are seldom designed with less than 70 percent of their weight on drivers, and for heavy freight service it is often practical to carry all of the weight on drivers. In other words the weight on drivers for electric locomotives may be 25 to 30 percent more than for steam locomotives due to the fact that the wheel arrangement may be different and because multiple-unit operation is feasible with electric locomotives.

These preliminary estimates are always subject to adjustments by locomotive builders.

Split-Phase Induction-Motor Locomotives

The split-phase induction-motor locomotive is inherently a constant-speed locomotive on account of the fact that the speeds of induction motors depend upon the frequency of the distribution system and the number of magnetic poles in the motor design.

In order to double the speed of an induction motor it is necessary to be able to reduce the number of poles to half, which is only feasible from an electrical standpoint when the number of magnetic poles is divisible by four.

The chief advantage of the split-phase induction-motor locomotive is due to its ability to regenerate power automatically and return it to the distribution system when

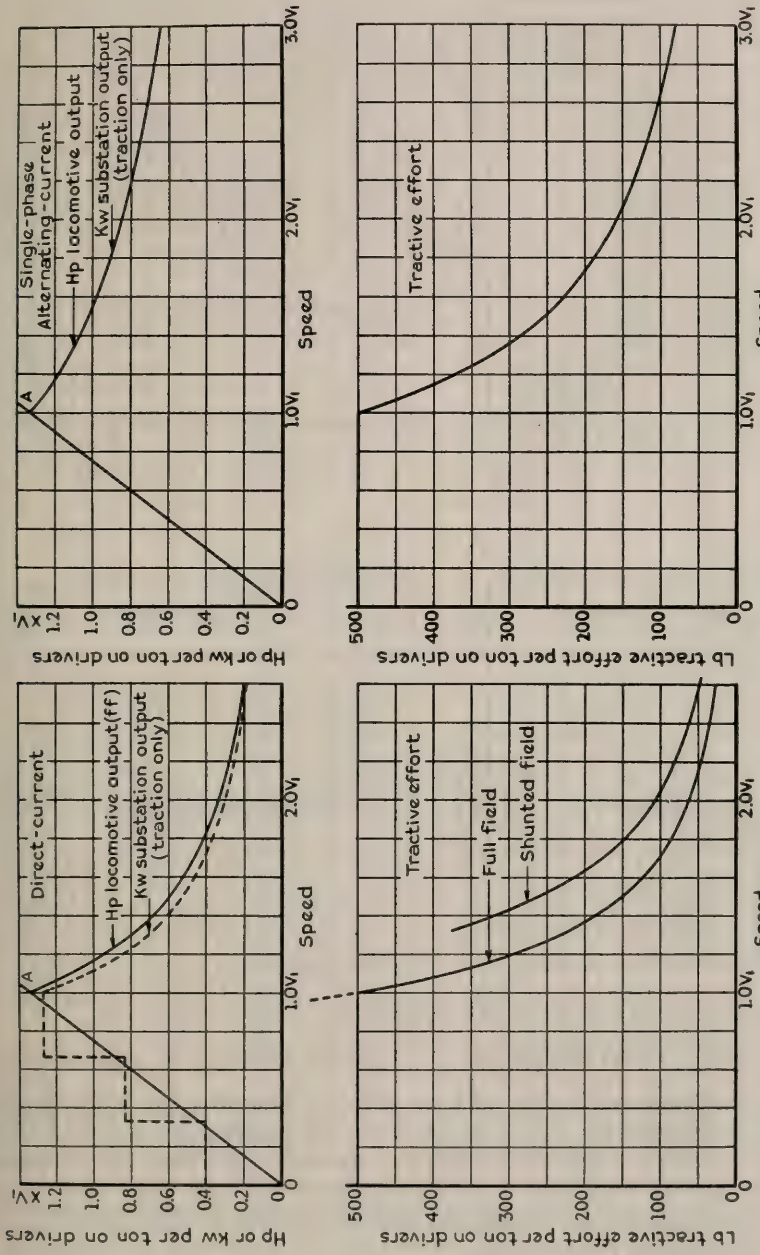

FIG. 3.—Typical Characteristic Curves, Direct-Current and Single-Phase Alternating Current.

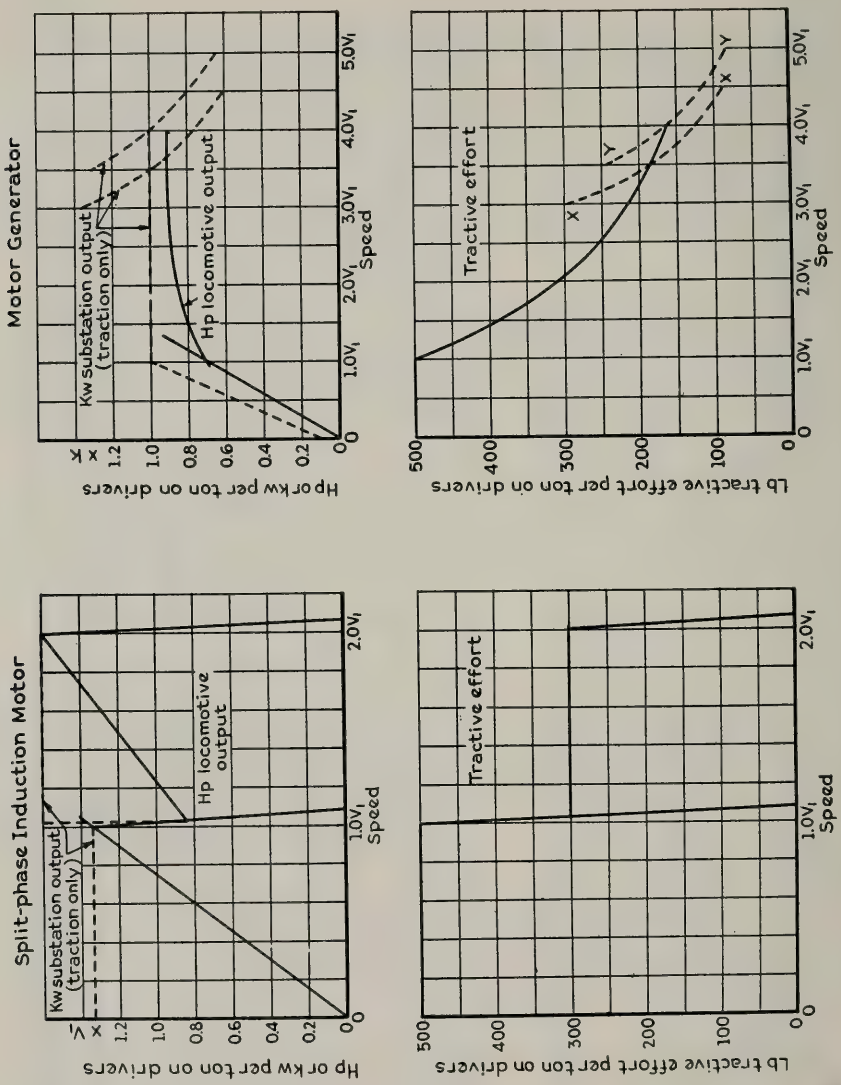

FIG. 4.—Typical Characteristic Curves, Split-Phase Induction Motor and Motor Generator.

operating on descending grades. All types of electric locomotives are capable of regenerating power under the same conditions if they are provided with a suitable control.

Fig. 4 shows typical characteristics of split-phase induction-motor locomotives. Their applications are limited on account of their constant-speed characteristics and for this reason the form for calculating the characteristic curves has been omitted.

Motor-Generator Locomotives

Motor-generator locomotives are essentially direct-current locomotives arranged to operate from a single-phase alternating-current trolley by installing a motor-generator set on the locomotive to convert alternating current into direct current.

FORM B

FORM FOR CALCULATING
THE TRACTIVE EFFORT AND HORSEPOWER OUTPUT
OF TYPICAL ELECTRIC LOCOMOTIVES
MOTOR GENERATOR LOCOMOTIVE

ITEM

1. Type (Wheel Arrangement)
2. Weight on Drivers (Tons)
3. Weight of Locomotive (Tons)

4. HP Rating of Mot-Gen Set
5. Max HP Rating (Pull Out) M-G Set

6. Rated Speed

7. Rated Tractive Effort

8. Rated HP M-G Set Per Ton on Drivers = K

9. V = .522 x Item (8)

Speed		Driver Tractive Effort		Locomotive Output		Substation Output	
V	MPH	Lbs per Ton on Drivers	Total	HP per Ton on Drivers	Total	KW per Ton on Drivers	Total
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
0	0	500		0	0	.100 x K	
1.00 x V_1		500		.696 x K		1.000 "	
1.25 "		437		.760 "		1.000 "	
1.50 "		386		.805 "		1.000 "	
1.75 "		344		.837 "		1.000 "	
2.00 "		308		.858 "		1.000 "	
2.25 "		279		.874 "		1.000 "	
2.50 "		254		.884 "		1.000 "	
2.75 "		233		.892 "		1.000 "	
3.00 "		215		.897 "		1.000 "	
x 3.50 "		185		.902 "		1.000 "	
y 4.00 "		163		.907 "		1.000 "	

Traction Motor Characteristics Full Gen. Voltage

3.00 x V_1		294		1.228 x K		1.362 x K	
3.25 "		231		1.046 "		1.160 "	
x 3.50 "		185		.902 "		1.000 "	
4.00 "		124		.690 "		.765 "	
4.50 "		87		.545 "		.605 "	

3.50 x V_1		244		1.185 x K		1.307 x K	
3.75 "		198		1.032 "		1.138 "	
y 4.00 "		163		.907 "		1.000 "	
4.50 "		114		.716 "		.790 "	
5.00 "		83		.580 "		.640 "	

xy Note effect of constant generator voltage

In principle, it is the same as oil-electric locomotives with an electric motor substituted for the oil engine. However, it is not essential to provide automatic control, consequently it may have some of the characteristics of direct-current locomotives.

Fig 4 and Form E show typical characteristic curves and a method for calculating the speed and tractive effort of motor-generator locomotives based on the horsepower capacity of the motor-generator set. Attention is called to the dotted curves on the diagram and the spaces provided on the form for calculating typical characteristic curves of the traction motors based on full voltage.

Electric Braking

There are two forms of electric braking which convert the stored energy in the train into electric energy and thus reduce the heating and wear of brake shoes and wheels. In one form which is known as dynamic braking the electric energy is wasted in heating resistances which are carried on the locomotive for this purpose. In the other form which is called regenerative braking, the electric energy is returned to the distribution system where it does useful work supplying power to other trains on the line or reducing the load on the power station.

When calculating the amount of power which can be converted into electric power it is necessary to consider the tractive capacity of the locomotive and the characteristics of the electrical equipment as well as the grades and the resistance of the train. Part of the stored energy of the train is lost in overcoming train resistance, the balance represents the amount available for conversion into electric energy.

Braking Effort

The braking effort of a locomotive is the force exerted at the driving axles to oppose its motion or the opposite of tractive effort. The maximum braking power of a locomotive is therefore limited by the same conditions which limit its maximum tractive power, except in practice it is customary to limit the maximum braking effort to 20 percent of the weight on drivers instead of 25 percent which is the amount generally assumed as the maximum tractive effort available for propelling the locomotive. Thus the tractive and braking capacities of a locomotive can be represented by the lines O-A and O-A′ respectively in Fig. 5.

The actual amount of electric power which can be generated is limited by the capacity of the equipment, its efficiency and characteristics. A typical tractive effort and regenerative braking diagram is shown in Fig. 5.

In the left-hand portion of the diagram the horsepower outputs of the locomotive when motoring are shown above the horizontal axis and the horsepower inputs to the drivers and the electrical outputs in kilowatts when braking, are shown below the horizontal axis. In the right-hand portion of the diagram the tractive efforts at various speeds are shown above the horizontal axis and the braking efforts below. The tractive effort characteristics are based on an allowance of about 10 percent for average voltage drop in the trolley, whereas no allowance has been made for over-voltage or voltage drop during regeneration because it is assumed that a kilowatt generated at the locomotive is equivalent to a kilowatt generated at the substation. Actually, there will be times during regeneration when the voltage at the locomotive will be higher than at the substation but in preliminary estimates this condition can be neglected.

Form F shows a work sheet for calculating the braking efforts obtainable at various speeds based on full speed and two-third speed combinations. Spaces are left at the bottom of the form for calculating the braking efforts corresponding to one-half or

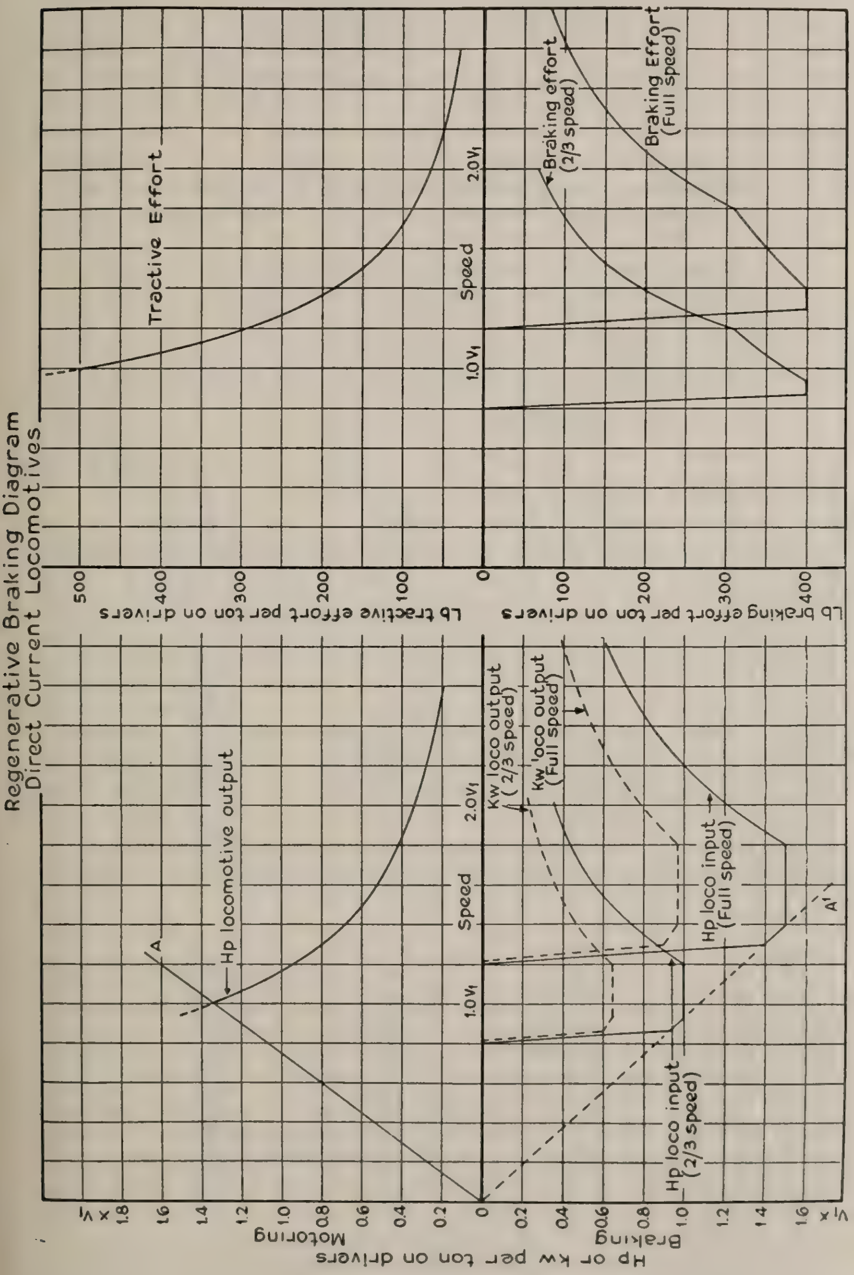

FIG. 5.—Regenerative Braking Diagram Direct Current Locomotives.

FORM FOR CALCULATING THE BRAKING EFFORT AND KW OUTPUT REGENERATED TYPICAL DIRECT CURRENT LOCOMOTIVES

FORM F

________________________ RAILROAD

Item

1. Type (Wheel Arrangement)________________________
2. Weight on Drivers (Tons)________________________
3. Weight of Locomotive________________________
4. Number of Motors________________________

5. Horsepower Continuous Rating________________________
6. Speed at Continuous Rating________________________
7. Tractive Effort Continuous Rating________________________

8. T.E. Continuous Rating per Ton on Drivers________________________
9. Speed (Cont. Rating) Corrected for Ave Line Voltage________________________

10. Maximum Safe Speed MPH________________________

Full Speed		Driver Braking Effort		Input Locomotive		Output Locomotive	
V	MPH	Lbs per Ton on Drivers	Total	HP per Ton on Drivers	Total	KW per Ton on Drivers	Total
1.00 x V_1							
		Fill out above spaces from Form C					
1.20 x V_1		0	0	0	0	0	0
1.30 "		400		1.387 x V_1		.900 x V_1	
1.40 "		400		1.494 "		.970 "	
1.50 "		373		1.494 "		.970 "	
1.60 "		350		1.494 "		.970 "	
1.80 "		311		1.494 "		.970 "	
2.00 "		227		1.210 "		.790 "	
2.20 "		171		1.004 "		.650 "	
2.40 "		131		.838 "		.550 "	
2.60 "		103		.714 "		.460 "	
2.80 "		83		.620 "		.400 "	
3.00 "		67		.536 "		.350 "	

2/3 Speed

.800 x V_1		0		0		0	
.867 "		400		.925 x V_1		.600 x V_1	
.933 "		400		.996 "		.647 "	
1.000 "		373		.996 "		.647 "	
1.067 "		350		.996 "		.647 "	
1.200 "		311		.996 "		.647 "	
1.333 "		227		.807 "		.527 "	
1.467 "		171		.670 "		.433 "	
1.600 "		131		.559 "		.367 "	
1.733 "		103		.476 "		.307 "	
1.867 "		83		.413 "		.267 "	
2.000 "		67		.357 "		.233 "	

Speed

one-third speed combination whichever combination is applicable to the particular locomotive in question. (One-half applies when the number of motors is a multiple of four and one-third when it is a multiple of six).

When applying these data to actual examples it is sometimes found that the braking efforts required to hold the train at the desired speed are less than given on the diagram or on the form. In these cases it is necessary to reduce the power regenerated in proportion to the braking efforts. When the braking efforts required to hold the train at the desired speed are greater than obtained on the form, it is necessary to assume that the excess braking effort will be supplied by the brakes on the train.

OIL-ELECTRIC LOCOMOTIVES AND RAIL CARS

Oil-electric locomotives are examples of a type of motive power which uses electrical means for transmitting power from a power unit to the drivers. Other examples which can be included in this class are gas-electric rail cars and turbo-electric locomotives. In all cases the basic principles are the same as for steam locomotives, except that in some instances different limits are assumed, as explained later.

Tractive Capacity

The maximum tractive capacity is limited by the adhesion between the drivers and the rails, which in the case of oil-electric locomotives is generally based on 30 percent of the weight on drivers instead of 25 percent used for steam locomotives, because the tractive effort which can be developed by overloading the traction motors is not a fixed maximum as it is in the case of steam locomotives. However in some cases it is necessary to limit the maximum tractive efforts arbitrarily to avoid exceeding the overload capacity of the electrical equipment. It is represented by the line O-A, Fig. 6.

Power Capacity

The amount of power available is limited the same as for steam locomotives by the capacity of the power unit (usually the manufacturer's rating) which is represented by the horizontal line E-C, Fig. 6. The maximum capacity is represented by the line E′-C′.

In some cases the power unit supplies power for operating the auxiliaries, such as air compressor, blowers, battery charging, etc. which amounts to two to seven percent of the rated capacity. The balance after deducting the power required for auxiliaries is the power available for traction and is represented by the horizontal line E″-C″, Fig. 6.

Locomotive Output

The locomotive output in the case of electric drive is equal to the engine output less the power required for auxiliaries, less the electrical and mechanical losses in the transmission. In practice the characteristics and efficiencies of motors and generators can be accurately determined from stand tests before the equipment is assembled on the locomotive. The control can then be designed and adjusted to limit the output of the power unit to any desired amount by compensating for the losses in the transmission.

In general, the combined efficiency of motors and generators corresponding to normal ratings will amount to 81 to 83 percent depending upon their capacity. If no allowances are necessary for auxiliaries, the nominal horsepower output of locomotive can be taken at 81 to 83 percent of engine capacity. If an allowance of 2 to 4 percent is made for auxiliaries, the nominal horsepower output will be around 80 percent.

If it is necessary to allow seven percent for auxiliaries, it is usually assumed that the equipment is small and the efficiency is *less* than for larger equipment. In this case

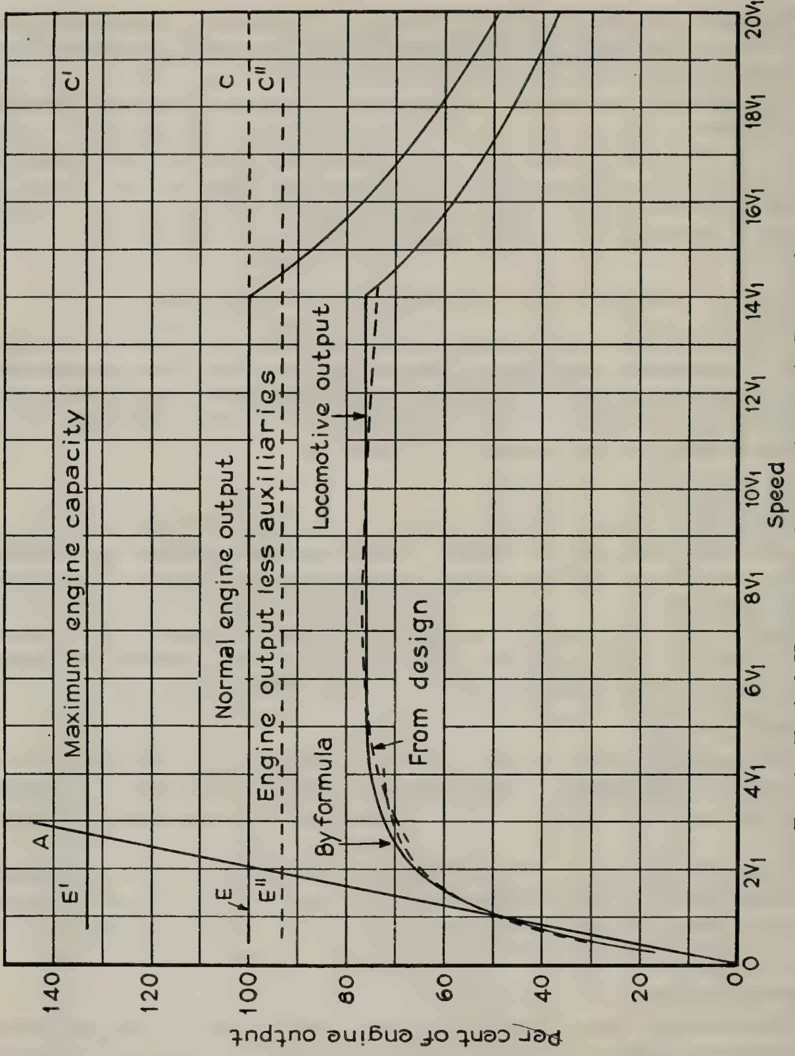

FIG. 6.—Typical Horsepower Curves Oil-Electric Locomotives.

the nominal horsepower output may be as low as 73 percent of the engine output, but 75 percent is generally assumed.

The dotted curve in Fig. 6 shows the horsepower output at the driving axles computed from design data. The solid curve is obtained by using Form G, which is based on an empirical formula similar to the one derived for steam locomotives.*

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* The formula is

Horsepower output per ton on drivers $= K\,(1 - e^{-u})$

where $K =$ nominal horsepower output per ton on drivers

$e =$ base of Naperian logarithms

$u = \dfrac{V}{V_1}$

V and $V_1 =$ speeds in miles per hour

FORM G

FORM FOR CALCULATING
THE TRACTIVE EFFORT AND HORSEPOWER OUTPUT
OF OIL-ELECTRIC LOCOMOTIVES

________________________RAILROAD

Item
1. Type (Wheel Arrangement)________________________
2. Weight on Drivers (Tons)________________________
3. Weight of Locomotive________________________

4. Rated Horsepower of Power Unit________________________
5. Horsepower Required for Auxiliaries________________________
6. *Nominal Horsepower Output of Locomotive________________________

7. Horsepower per ton on Drivers Item (6)/Item (2) = K________________________
8. V_1 = .395 x Item (7)________________________

Normal Gearing				Special Gearing				Horsepower Output	
Speed		Driver		A		B			
V	MPH	Tractive Effort Lbs.Per Ton on Drivers	Total	MPH	Driver T.E. Total	MPH	Driver T.E. Total	Per Ton on Drivers	Total
(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(j)	(k)
0	0	600		0		0		0	0
1.00xV_1		600						.632xK	
1.25 "		542						.713 "	
1.50 "		492						.777 "	
1.75 "		448						.826 "	
2.00 "		411						.865 "	
2.50 "		348						.918 "	
3.00 "		300						.950 "	
3.50 "		263						.970 "	
4.00 "		233						.982 "	
4.50 "		209						.989 "	
5.00 "		189						.993 "	
6.00 "		158						.998 "	
7.00 "		135						.999 "	
8.00 "		119						1.000 "	
10.00 "		95						1.000 "	
12.00 "		79						1.000 "	
14.00 "		67						1.000 "	
1.10xV'								(U).911 "	
1.20 "								(X).833 "	
1.30 "								(Y).761 "	
1.40 "								(Z).714 "	

*Nominal horsepower output of locomotive depends upon engine capacity and allowances for auxiliaries.

Assume 80 per cent (78-82) of Item (4) for road locomotives
75 per cent (73-77) of Item (4) for switch locomotives and rail cars including auxiliaries

(U) (X) (Y) (Z) are the horsepower outputs corresponding to 10, 20, 30 and 40 per cent over speed (after generator reaches full voltage)

Spaces A and B are provided in case it is necessary to change motor gearing to meet high speed conditions.

Speed Tractive Effort Curves—Oil-Electric Locomotives

Form G shows a typical work sheet similar to the ones for steam and electric locomotives for calculating the speed, tractive effort and horsepower outputs of oil-electric, or turbo-electric locomotives and gas-electric rail cars based upon the horsepower capacity of the power unit and the weight on drivers. The speeds and drive tractive efforts corresponding to normal gearing are calculated first and entered in Cols. (b) and (d) and the horsepower outputs in Col. (k). For normal gearing, $V_1 = 0.395 \times K$ and corresponds to a tractive effort of 600 lb. per ton on drivers or 30 percent of the weight on drivers.

This gearing which usually corresponds to maximum reduction (minimum motor pinion) limits the speed range over which the full capacity of the power unit can be used to about $10 \times V_1$ without shunted field and to about $14 \times V_1$ with shunted field control, provided the generator is wound for the same voltage as the motors. At higher speeds the tractive efforts fall off rapidly with increases in speed due to the characteristics of the electrical equipment which automatically reduces the load on the power unit.

The reduced horsepowers (U), (X), (Y) and (Z), which correspond 10, 20, 30 and 40 percent increases in V', are given in order to be able to adjust the tractive efforts at these high speeds and reduced outputs. The speed represented by V' may correspond to any value of V between $8 \times V_1$ and $14 \times V_1$, depending upon design data—motor and generator voltages, type of control, etc.

If it is desired to use the full capacity of the power unit over a higher speed range than indicated for normal gearing, it is necessary to change the motor gearing. For example, if it is desired to obtain full engine capacity up to $20 \times V_1$ instead of, say, $10 \times V_1$ the speeds in Col. (b) would be doubled and entered in Col. (e) and the tractive efforts in Col. (d) would be halved and entered in Col. (f). The speeds and tractive efforts corresponding to any other gear ratio would be obtained in like manner and entered in Cols. (g) and (h).

In the case of double-speed gearing, for example, the tractive effort for the same overload on the electrical equipment would be limited to 300 lb. per ton on drivers, otherwise the losses might be excessive and the overloads injurious to the equipment. For these reasons it is necessary to depend upon designing engineers for the final selection of equipment and gearing to meet operating conditions.

Example.—Calculate the typical speed tractive effort curve of the following switching locomotive.

B-B-234 ÷ 234-900-hp. oil-electric locomotive

Continuous rating 33,600 lb. at 8.1 m.p.h.

Solution.—Rated tractive effort per ton on drivers equals 33,600 ÷ 117 or 287 lb. Refer to Form G and find in Col. (c) 300 and 263 lb. corresponding to $3 \times V_1$ and $3.5 \times V_1$ respectively. By interpolation, 287 lb. corresponds to $3.31 \times V_1 = 8.1$ m.p.h. or $V_1 = 2.447$ m.p.h. and K, nominal horsepower per ton on drivers, $= 2.447 \div 0.395$, or 6.197 and the nominal horsepower output of the locomotive equals 117×6.197, or 725.

The items 1 to 8, Form G, can now be filled in as follows and the speed tractive effort curves calculated.

1.	Type (wheel arrangement)	B-B
2.	Weight on drivers—234,000 lb.	117 tons
3.	Weight of Locomotive—234,000 lb.	117 "
4.	Rated horsepower of power unit	900
5.	Horsepower required for auxiliaries	
6.	Nominal horsepower output of locomotive (see above)	725
7.	Horsepower per ton on drivers	6.197
8.	$V_1 = 0.395 \times 6.197$	2.447

Locomotive Classification

The design and construction of oil-electric locomotives and others of this class have followed along the lines of electric locomotives and motor cars, therefore it is customary to classify them by their wheel arrangement in accordance with the electric system described earlier.

Weight and Capacity

At the present time there are not sufficient statistical data available to attempt an analysis of the relation between engine horsepower capacity and weight of locomotive along the lines discussed in the sections on steam and electric locomotives. For preliminary estimates regarding weights it can be roughly assumed that for the same horsepower capacity, oil-electric locomotives will weigh more than the engine and nearly as much as the engine and tender of steam locomotives as determined by Table I. At the same time, oil electric locomotives will generally have two or more times as many driving axles as steam locomotives of the same capacity and, hence, can have nearly twice as much weight on drivers, therefore the maximum tractive effort in some cases can easily be twice as much in starting as that for comparable steam locomotives.

PERFORMANCE AND FUEL OR ENERGY CONSUMPTION

The chief purpose of speed-tractive effort and horsepower curves is to estimate the performance and the fuel or energy consumption in service. For quick estimates the amount of work done or the net energy in foot-pounds required to move a train of a given weight over a known profile can be easily obtained by multiplying the distance traveled in feet by the train resistance in pounds per ton including the resistance due to grades and curves, times the weight of train and locomotive. Down-grade sections where the grade effect exceeds the train resistance including the resistance due to curves are neglected in these calculations because the excess energy due to the grade is generally not recovered but wasted in the brakes.

Such estimates are independent of the type of motive power used and do not include any allowances for acceleration and braking or other losses which are inherent in various types of motive power. It is a convenient way to compare the energy or fuel consumption by various routes provided the consumption by one route is known.

To estimate the fuel or energy consumption more accurately it is necessary to calculate the performance of the particular type of locomotive proposed, based on its speed tractive effort curves, the type and weight of train and the profile of the district. The calculations are known as speed-time-distance calculations which constitute a step-by-step process that approximates the results obtained from dynamometer-car tests.

SPEED-TIME-DISTANCE CALCULATIONS, STEAM LOCOMOTIVES

For those who are not thoroughly familiar with speed-time-distance calculations a typical example has been assumed to illustrate some of the steps.

The first step is to prepare a condensed profile showing the distance, elevation, and total degrees of curvature (central angle), etc.

Assumed Profile

Miles Per Hour	*Elev.*	*Degs. Curvature*	*Percent Grade*			
			Eastbound		*Westbound*	
			Actual	*Comp.*	*Actual*	*Comp.*
0	80	713	—.063	—.033	+.063	+.093
18	20	500	—.032	0	+.032	+.064
30	0					

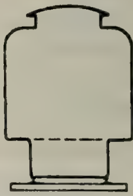
LOCOMOTIVE AND MOTOR CAR SERVICE

SYMBOLS

R = Tractive resistance in pounds per ton (2000 lb.) on tangent level track.
A = Area in square feet of cross-section of locomotive or car body and trucks.
V = Speed in miles per hour.
n = Number of axles per car.
w = Average weight per axle in tons.
wn = Average weight of locomotive or car.

VALUES OF A

Locomotives: 50 tons........	105 sq. ft.
" 70 tons........	110 "
" 100 tons and over	120 "
Freight cars................	85-90 "
Passenger cars.............	120 "
Multiple-unit cars..........	100-110 "
Motor cars: 2 trucks..	80-100 "
" " 1 truck.	70- 75 "



WHERE USED	USUAL FORMULAS Recommended for convenience in calculation. Approved for axle weights in excess of 5 tons.	GENERAL FORMULAS Applicable to all axle weights. To be used when axle weights are less than 5 tons
Locomotives.... ..	$R=1.3+\frac{29}{w}+0.03\ V+\frac{0.0024\ A\ V^2}{wn}$	$R=\frac{9.4}{\sqrt{w}}+\frac{12.5}{w}+0.03\ V+\frac{0.0024\ A\ V^2}{wn}$
Freight Cars.......... .	$R=1.3+\frac{29}{w}+0.045\ V+\frac{0.0005\ A\ V^2}{wn}$	$R=\frac{9.4}{\sqrt{w}}+\frac{12.5}{w}+0.045\ V+\frac{0.0005\ A\ V^2}{wn}$
Passenger Cars (Vestibuled)	$R=1.3+\frac{29}{w}+0.03\ V+\frac{0.00034\ A\ V^2}{wn}$	$R=\frac{9.4}{\sqrt{w}}+\frac{12.5}{w}+0.03\ V+\frac{0.00034\ A\ V^2}{wn}$
Multiple-unit Trains: Leading Car. (Vestibuled)	$R=1.3+\frac{29}{w}+0.045\ V+\frac{0.0024\ A\ V^2}{wn}$	$R=\frac{9.4}{\sqrt{w}}+\frac{12.5}{w}+0.045\ V+\frac{0.0024\ A\ V^2}{wn}$
Multiple-unit Trains: Trailing Cars.	$R=1.3+\frac{29}{w}+0.045\ V+\frac{0.00034\ A\ V^2}{wn}$	$R=\frac{9.4}{\sqrt{w}}+\frac{12.5}{w}+0.045\ V+\frac{0.00034\ A\ V^2}{wn}$
Motor Cars............	$R=1.3+\frac{29}{w}+0.09\ V+\frac{0.0024\ A\ V^2}{wn}$	$R=\frac{9.4}{\sqrt{w}}+\frac{12.5}{w}+0.09\ V+\frac{0.0024\ A\ V^2}{wn}$

EXPLANATORY NOTE

The first two terms of the equations represent journal friction almost entirely. They have been derived from dynamometer and coasting tests on standard freight and passenger cars and electric locomotives and are based on oil lubrication with average temperature conditions. Journal friction may be increased 20 to 40 per cent at temperatures below freezing.

The third term comprises resistances due to flange friction, concussion, swaying, and miscellaneous frictions proportional to the speed. The factor for this element is decreased by increase in length of truck wheel base and increased by poor road bed conditions and inferior riding qualities of motor cars.

The last term gives air resistance for average weight of car or locomotive in pounds per ton for standard types of equipment. No allowance is made for head winds or strong side winds.

Locomotive resistance represents tractive effort delivered to driving axles and does not include friction losses in gears, motor bearings or other parts of the driving equipment, as these are usually covered in the motive power efficiency.

The formulas are based on tests taken under mild weather conditions. Values obtained from them may be used as found in calculations relating to electric distributing systems, substations, energy consumption, and power demand. In the determination of electric motor characteristics and gear reductions to meet particular speed requirements, however, it may be desirable to add a small percentage to the required speed as a protection against unusual conditions.

Fig. 7.—Train Resistance Formulas—W. J. Davis, Jr.

Given the weight of train, and type of equipment, the next step is to determine the tractive resistance of the locomotive and train on level tangent track.

Assume the locomotive is a 2–10–4 type weighing 278 tons of which two-thirds or 185 tons is on drivers and which is equipped with an 8-axle tender weighing 203 tons loaded.

Using the Davis formulas, Fig. 7, the tractive resistance per ton is obtained as follows:

Tractive Resistance of Locomotive

2–10–4–8–8 (16 axles)

Miles Per Hour	10	15	20	25	30	35
$1.30 + 29/W$	2.27	2.27	2.27	2.27	2.27	2.27
$0.03V$	.30	.45	.60	.75	.90	1.05
$0.0024 \times 120 \times V^2/481$	.06	.14	.24	.38	.54	.74
	2.63	2.86	3.11	3.40	3.71	4.06
Total 481 tons	1265	1376	1496	1635	1785	1953

Tractive Resistance of 80-Ton Freight Cars

Miles Per Hour	10	15	20	25	30	35
$1.30 + 29/W$	2.75	2.75	2.75	2.75	2.75	2.75
$0.45V$	.45	.68	.90	1.13	1.35	1.58
$.0005 \times 90 \times V^2/80$	.06	.13	.22	.34	.51	.67
	3.26	3.56	3.87	4.22	4.61	5.00
Total 12,100 tons	39,446	43.076	46,827	51,062	55,781	60,500
Total Locomotive	1,265	1,376	1,496	1,635	1,785	1,953
Locomotive and Train	40,711	44,452	48.323	52,697	57,566	62,453
Total ÷ Tons on Drivers	220.0	240.0	261.8	285.3	310.9	338.8

In order to avoid large numbers it is simpler for the purpose of illustration to express the weights and resistances on the basis of one ton on drivers as shown directly above.

The next step is to calculate the speed-tractive effort curve of the locomotive. Based on the ratio of the weight on drivers and the weight of the engine (0.667), the capacity from Table I amounts to 30 horsepower per ton on drivers. Using Form A, calculate and plot the speed-tractive effort curves based on 30 hp. per ton on drivers.

Now refer to the sample calculations, Form H. On the first line Column (a) enter the miles per hour corresponding to V_1 (equals 30×0.396 or 11.88 mph.) and in Column (b) enter the corresponding tractive effort (from Form A 480 lb. per ton on drivers).

The tractive resistance of train and locomotive on level tangent track corresponding to 11.88 mph. amounts to 227.5 lb. based on 68 tons per ton on drivers. The resistance due to grade amounts to 20 lb. per ton times the percent grade. The actual grade over the first section of the assumed profile amounts to $\frac{(20\text{–}80) \times 100}{18 \times 5280}$ or minus 0.063 percent.

If there were no curves the resistance due to the grade would amount to $20 \times 0.063 \times$ the weight of the train (68 tons) or minus 85.7 lb.

The resistance due to curvature is generally assumed to amount to 0.8 lb. per ton per degree of curve which has the same effect as a difference in elevation of 0.04 ft. per degree of central angle. Thus 713 deg. of central angle in the first section is equivalent to a difference in elevation of 28.5 ft., leaving a net difference of 31.5 ft. eastbound and 91.5 ft. westbound.

The equivalent grade eastbound is therefore —0.033 percent and the resistance —0.66 lb. per ton or —45 lb. based on 68 tons as shown in Column (d).

The total resistance shown in Column (e) is therefore equal to the algebraic sum of Column (c) and Column (d) or 227.5 — 45.0 equals 182.5.

The net tractive effort, Column (f), is equal to the algebraic difference between Column (b) and Column (e) or 480 — 182.5 equals 297.5 lb.

FORM H

TYPICAL SPEED-TIME-DISTANCE CALCULATIONS
Weight on Drivers 185 tons
Wt of Eng & Tender 481 tons equals 2.6 tons/ton on Drivers
Wt of Train 12100 tons equals 65.4 tons/ton on Drivers
Total 12581 tons equals 68.0 tons/ton on Drivers

M.P.H.	Tractive	Tractive Resistance			Net	★ Accel.	Time		Distance		
	Effort	Train	Grade	Total	T.E.		Int'val	Total	Int'val	Total	Remarks
a	b	c	d	e	f	g	h	i	j	k	MP–0
11.88	480	227.5	–45.0	182.5	297.5	.0458	259.5		2260	Grade	–.033%
	476	233.7	–45.0	188.7	287.3	.0442	70.5		1390		
15.0	472	240.0						330.0		3650	
	464	245.4	–45.0	200.4	263.6	.0406	61.6		1470		
17.5	456	250.9						391.6		5120	
	444.5	256.3	–45.0	211.3	233.2	.0359	69.6		1915		
20.0	433	261.8						461.2		7035	
	421	267.6	–45.0	222.6	198.4	.0305	81.9		2552		
22.5	409	273.5						543.1		9587	
	397	279.4	–45.0	234.4	162.6	.0250	99.9		3480		
25.0	385	285.3						643.0		13067	
	373	291.7	–45.0	246.7	126.3	.0195	128.5		4950		
27.5	361	298.1						771.5		18017	
	349	304.5	–45.0	259.5	89.5	.0138	181.4		7650		
30.0	337	310.9						952.9		25667	
	326	317.3	–45.0	272.8	53.2	.0082	305.0		13980		
32.5	315	324.8						1257.9		39647	
	304.5	331.8	–45.0	286.3	17.7	.0027	918.0		45450		
35.0	294.0	338.8						2175.9		85097	
	294.0	338.8	–45.0	293.8	–	–	193.7		9943		
35.0	294.0							2369.6		95040	MP 18
									Grade	Change	0.0
	304.5	331.8	–		–27.3	–.0042	545.0		27000		
32.5	315.0	324.8						2914.6		122040	
	317.0	322.4	–		–5.4	–.0008	600.0		28400		
32.0	319.0	320.0						3514.6		150440	
	319.0	320.0	–				57.1		2680		
32.0	319.0							3571.7		153120	
							225.0		5280		Stop
0								3796.7		158400	MP 30

★Net T.E. required to produce 1.0 M.P.H.P.S. = 95.5 x 68 = 6494 lb

The acceleration, Column (g), is obtained by dividing the net tractive effort, Column (f), by 95.5 times the total weight of the train including locomotive. Thus $297.5 \div 95.5 \times 68$ equals 0.0458 miles per hour per second.

It can be shown theoretically that it takes a force of 91.1 lb. per ton to produce an acceleration of 1.0 mile per hour per second, but it is customary to add about 5 percent to the theoretical force to take care of the inertia of the revolving parts which require an additional force to start them rotating. This adjustment is included in the factor 95.5.

The time interval in seconds, Column (h), is obtained by dividing the speed, Column (a), by the acceleration, Column (g), thus $11.88 \div 0.0458$ equals 259.5 sec.

The distance traveled in feet, Column (j), is equal to the product of Column (h) times the average speed in miles per hours times 1.467. (1.0 mph. $= \frac{5280}{3600}$ or 1.467 ft. per sec.).

Thus, for the first interval the distance traveled amounts to $\frac{259.5 \times (11.88 + 0) \times 1.467}{2}$ equals 2,260 ft.

For the second step in the calculations select a convenient point on the speed tractice effort curve, say 15 mph., and enter the corresponding tractive effort resistances on the third line under Columns (b) and (c), namely 472 and 240.0, respectively.

The average acceleration, Column (g), during this interval is based on the average net tractive effort obtained by subtracting the average tractive resistance from the average tractive effort as indicated by the figures on the second line.

The time interval, Column (h), is obtained by dividing the difference in speed by the average acceleration, that is, $(15 - 11.88) \div 0.0442$ equals 70.5 sec.

The corresponding distance traveled is obtained by multiplying the interval of time by the average speed times 1.467. Thus the distance amounts to

$$\frac{70.5 \times (15.0 + 11.88) \times 1.467}{2} \text{ equals } 1{,}390 \text{ ft.}$$

The total time and the total distance required to reach the speed shown in Column (a) are obtained by adding the time or distance intervals and entering the sums on the third line in Columns (i) and (k).

The third step and all succeeding steps are the same as the second step described above.

Momentum Grades.—In cases involving momentum grades it is often necessary to take account of the length of the train because the grade resistance gradually increases until the entire train is on the grade. An example of this kind is described in a report of Committee 21—Economics of Railway Operation Vol. 39 pages 550–556.

Fuel or Energy Consumption

The foot-pounds of work done at the driving axles of the locomotive can be obtained by taking the sum of the products of the tractive efforts, Column (b), times the corresponding distances, Column (j), as shown below.

In the case of steam locomotives the foot-pounds of work done in the cylinders is equal to the sum of the work done at the driving axles, plus the mechanical losses in the engine, which are assumed to amount to 20 lb. per ton on drivers, times the distance traveled in feet.

To convert foot-pounds to horsepower-hours divide by 1,980,000.

Boiler Output.—The driver and cylinder horsepower-hours are not true measures of steam and coal consumption, but they have been used for this purpose in connection with dynamometer car tests. It is simpler and more accurate to use the boiler output as explained in the following paragraphs.

Boiler output can be expressed in two ways, first in terms of evaporation and second in terms of horsepower.

The boiler output in horsepower is assumed constant at all speeds above V_1 and equal to the normal capacity of the locomotive. For speeds below V_1 it is assumed the boiler horsepower is proportional to the steam consumption.

Assuming the cylinders are filled twice every revolution as long as the speed does not exceed V_1—which corresponds to full cutoff—the amount of steam delivered to the cylinders will depend upon the number of revolutions required to reach a speed equal to V_1 or, in other words, upon the distance traveled during the first period (Column (g), first line sample calculations).

TABULATION FOR OBTAINING DRIVER HORSEPOWER-HOURS

Tractive Effort Col. (b)	*Distance Feet Col. (j)*	*Product (000 Omitted)*
480	2,260	1,085
476	1,390	662
464	1,470	682
444.5	1,915	851
421	2,552	1,074
397	3,480	1,382
373	4,950	1,846
349	7,650	2,670
326	13,980	4,557
304.5	45,450	13,840
294	9,943	2,923
304.5	27,000	8,222
317	28,400	9,003
319	2,680	855
	153,120	49,652

Hp.-hrs. output $= 49{,}652 \div 1{,}980 = 25.08$ per ton on driver,

I.hp.-hrs. $= \dfrac{49{,}652 + 20 \times 153.12}{1{,}980} = 26.62$ per ton on drivers,

hp.-hrs. boiler output (explained below) $=$

$$\frac{(3{,}571.7 - 2/3 \times 259.5)\ 30}{3{,}600} = 28.32 \text{ per ton on driver}$$

Since the distance traveled is proportional to the square of the time, it can be shown that the amount of steam used during the first interval is equal to one-third of the normal consumption, consequently the average horsepower output during the first step is equal to one-third of normal capacity.

The horsepower output of the boiler for the entire run is therefore equal to the product of the normal horsepower capacity times the hours the locomotive is working at normal capacity adjusted for the time it averages only one-third of capacity. The adjustment amounts to two-thirds of the time shown on the first line of Column (h) subtracted from the time the locomotive is working.

Thus, on the basis of the sample calculations, the locomotive is working at normal capacity (30 hp. per ton on drivers) for 3,571.7 sec. less two-thirds of 259.5 sec. or 3,398.7 sec., therefore the

$$\text{Boiler output} = 30 \times \frac{3{,}571.7 - 2/3 \times 259.5}{3{,}600} = 28.32 \text{ hp.-hrs.}$$

per ton on drivers, or 185 × 28.32 equals 5,238 hp.-hrs. total output for the locomotive.

Evaporation.—The amount of steam required for a given run will be equal to the product of the horsepower-hours output of the boiler, times the steam factor (pounds of steam per horsepower-hour). The steam factor depends upon the steam pressure, degrees of superheat and design experience. For modern steam locomotives the steam factor frequently assumed is 15 lb. steam per horsepower-hour excluding auxiliaries based on high pressure and high superheats.

On this basis, the steam to the cylinders for the sample calculations will amount to 15 × 5,238 or 78,570 lb., to which should be added a liberal allowance for auxiliaries.

Fuel Consumption.—Based on present day practice of high pressures and superheats it requires the transfer of about 1,300 B.t.u. to produce one pound of steam. If there are 10 times as many B.t.u. in a pound of coal as in a pound of steam, one pound of coal would evaporate ten pounds of water, based on 100-percent efficiency. The boiler efficiency depends first of all upon design experience and varies with the rate of firing and the quality of fuel.

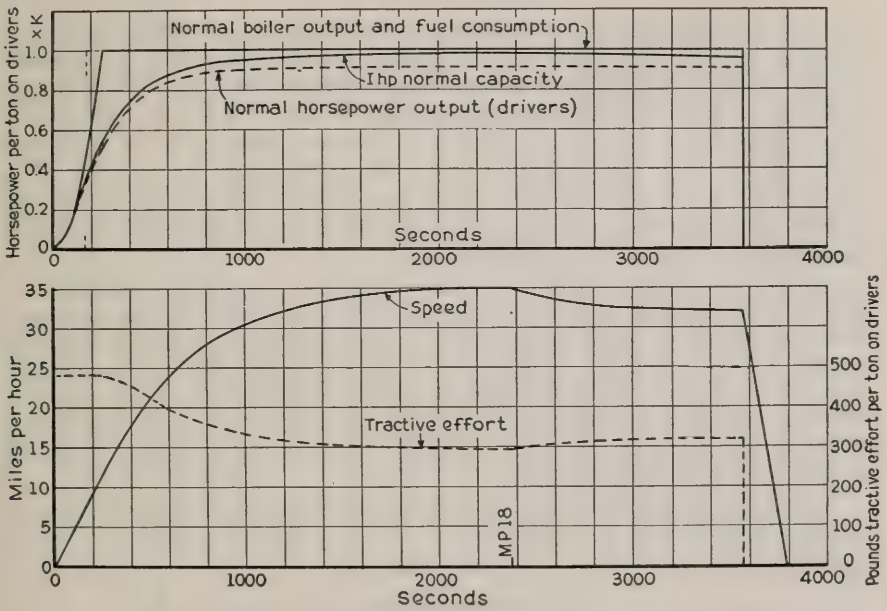


Fig. 8.—Typical Speed-Time and Fuel Consumption Curves Steam Locomotives.

Since the speed tractive effort curves are based on constant boiler output it is assumed that the firing rate and efficiency also remain constant. The following table giving the evaporative capacity of coals of various qualities is based on normal firing rates and a boiler efficiency, exclusive of feed-water heaters, of about 70 percent. Savings by feed-water heaters are estimated to be about 8 percent.

The fuel consumption for the sample calculations based on the use of feed-water heaters and 13,000-B.t.u. coal would amount to 78,570 ÷ 7.6, or 10,340 lb., exclusive of the coal required for auxiliaries.

The coal for auxiliaries and for standby losses should be estimated separately in order that adjustments can be made for various assumptions without upsetting the basic calculations.

APPROXIMATE POUNDS OF WATER EVAPORATED PER POUND OF COAL OF VARIOUS QUALITIES BASED ON NORMAL FIRING RATES

Quality	*Without Feedwater Heater*	*With Feedwater Heater*
15,000 B.t.u. per lb.	8.0	8.6
14,000	7.5	8.1
13,000	7.0	7.6
12,000	6.4	6.9
11,000	6.0	6.5
10,000	5.4	5.8
9,000	4.8	5.2
8,000	4.3	4.6

Electric Locomotives

The speed-time-distance and horsepower-output calculations for electric locomotives are similar to those outlined for steam locomotives. The simplest method to determine the kw. output of substations is to plot the speed-tractive effort and output curves, from Form C or D; then the output corresponding to any speed can be read from the chart. The next step is to plot an output-time curve corresponding to the speed-time curve. The area under the curve will represent the kw-hrs. output of substations.

To find the area under the output curve based on speed-time-distance calculations, multiply the average output for each step in the calculations by the time Column (h), take the sum of the products and divide by 3,600.

In the case of direct-current locomotives it is necessary to make an adjustment on account of the losses in the starting resistances as explained earlier. For example, with rheostatic control the output of substations is constant during the first step and equal to $1.270 \times V_1 \times$ tons weight on drivers, hence the output times the seconds required to reach V_1 will give the kw.-sec. during the period when the resistances are being cut out. With series-parallel control the substation output averages 74 percent of the output with rheostatic control and for three-speed control the substation output averages 66 percent of the output for rheostatic control.

In the case of alternating locomotives the substation output during the first period amounts to $\frac{1}{2} \times 1.333\ V_1 \times$ tons weight on drivers times the seconds required to reach V_1.

Oil-Electric Locomotives

The speed-time-distance and engine-output calculations for oil-electric locomotives or motor-generator locomotives are practically the same as for steam locomotives because it is assumed that the output of the engine remains constant except during the first period.

The horsepower output of the engine for the entire run is therefore equal to the product of the normal horsepower capacity times the hours the locomotive is working at normal capacity adjusted for the time when the engine is only partially loaded. The adjustment amounts to one-half of the time shown on the first line Column (h) subtracted from the time locomotive is working (see also Form H).

If power for the auxiliaries is furnished by the main power unit care must be used to estimate the auxiliary power and standby losses separately.

Fuel Consumption.—Inasmuch as the speed tractive effort curves of oil-electric locomotives are based on constant speed and constant output of the engine the fuel consumption per hour is assumed constant.

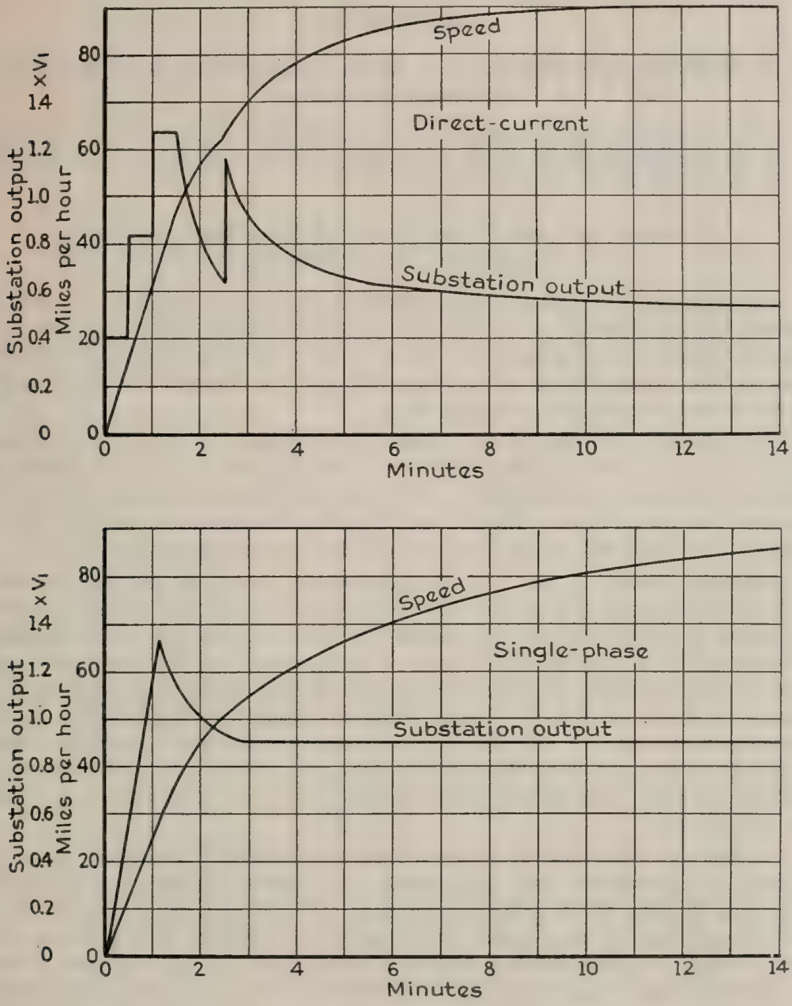


FIG. 9.—Typical Speed-Time and Energy Consumption Curves Electric Locomotives.

Since the fuel consumption per shaft horsepower-hour can be determined by stand tests before the engine is assembled on the locomotive it is possible to obtain actual fuel consumption rates or the thermal efficiency from tests.

For estimating purposes the fuel consumption is generally based on a thermal efficiency of 25 to 30 percent (0.5 to 0.6 lb. of fuel oil per shaft horsepower hour).

Appendix B

(2) Methods for Obtaining a More Intensive Use of Existing Railway Facilities

L. E. Dale (chairman, subcommittee), E. Y. Allen, B. T. Anderson, Geo. W. Hand, E. A. Humphreys, W. B. Irwin, J. F. Pringle, C. P. Richmond, B. J. Schwendt, H. A. Shinkle, H. W. Williams.

Consolidation—West Jersey & Seashore and the Atlantic City Railroads

The properties of the West Jersey & Seashore Railroad—a leased line of the Pennsylvania Railroad Company,—and the Atlantic City Railroad—a line controlled by the Reading Company—were unified on June 26, 1933, to form the Pennsylvania–Reading Seashore Lines. These lines of railroad serve Southern New Jersey, including the seashore resorts between Atlantic City and Cape May.

The predominating traffic of each railroad was passenger. In 1926 passenger revenues were 56 percent of total operating revenue; in 1929 they were 47 percent. During 1926 passenger train-miles were 4,409,542 and freight train-miles were 822,596, during 1929 passenger train-miles were 3,273,830, and freight train-miles were 596,742. The full capacity of each line was frequently required to handle the traffic peaks.

Operating revenues of the two railroads were $17,723,006 in 1926 and $14,423,713 in 1929, a decrease of 18.6 percent. They were $5,867,202 for the P.–R.S.L. in 1934, a decrease of 66.9 percent from 1926. Passenger revenues in 1926 were $10,004,781 and in 1929, $6,769,717, a decrease of $3,235,064, or 32.3 percent. For the same period freight revenues were $6,889,297 in 1926 and $6,834,064 in 1929, substantially unchanged. The decrease of about one-third in passenger revenues reflects a diversion of this traffic to the highway. The effect of the depression period starting the latter part of 1929 was to reduce the total volume of traffic so that in 1934 passenger revenues were $2,759,921, or 72.4 percent, under those of 1926, and freight revenues were $2,803,708, or 59.3 percent less than in 1926.

In 1932, the two separately operated lines were handling a greatly reduced volume of traffic on a competitive basis, that is, there was an excess of facilities and a duplication of services. Analysis of the individual operation of the lines during the years 1931 and 1932 showed that by consolidating the properties and unifying the operations, excess facilities could be abandoned and duplicated services discontinued to produce estimated net annual savings in operating costs of $1,452,211. This is set forth in the tabulated statement.

STATEMENT OF ESTIMATED ANNUAL SAVINGS
OPERATING COSTS

Facilities Abandoned and Services Eliminated		*Estimated Annual Savings*
78.2 Miles of line—134.4 Track miles—		
Maintenance	$310,876	
Operation (other than train)	260,046	
Taxes	196,695	
		$ 767,617
Industrial and terminal switching—		
876 Switching days		48,171

PROPERTY INVESTMENT AND
Miles of road operate
Investment in railway
Accrued depreciation
Total operating reven
Total operating expen
Operating ratio
Net operating revenue
Taxes
Equipment rents
Joint facility rents
Total expenses, taxes
Net railway operating
Other income
Fixed charges
Net income
FREIGHT SERVICE STATIST
Revenue tons carried
Freight revenue (Acct
Freight proportion of
Revenue ton-miles
Net ton-miles
Gross ton-miles (excl
Freight train-miles
Loaded freight car-mi
Total freight car-mil
Average revenue per t
Average haul per reve
Gross ton-miles per f
Loaded car-miles per
Total car-miles per f
Freight proportion of
Net ton-miles per loa
PASSENGER SERVICE STATI
Revenue passengers ca
Passenger revenue (Ac
Passenger proportion
Revenue passenger-mil
Passenger train-miles
Passenger car-miles
Average revenue per p
Average journey per p
Passenger car-miles p
Passenger proportion

COMPARATIVE STATEMENT OF FINANCIAL AND OPERATING RESULTS OF ATLANTIC CITY R.R. AND WEST JERSEY & SEASHORE R.R COMBINED IN YEARS 1926 AND 1929 WITH PENNSYLVANIA-READING SEASHORE LINES IN YEARS 1934 AND 1937

Item	1926			1929			1934	1937
	Atlantic City R.R.	West Jersey & Seashore	Total combined	Atlantic City R.R.	West Jersey & Seashore	Total combined	Penna-Reading Seashore Lines	Penna-Reading Seashore Lines
PROPERTY INVESTMENT AND INCOME ACCOUNT ITEMS:								
Miles of road operated	161.27	378.97	540.24	163.90	369.47	533.37	413.67	412.28
Investment in railway property used in transportation service	$15 831 740	$31 904 684	$47 736 424	$16 000 773	$32 467 627	$48 468 400	$44 961 870	$39 250 961
Accrued depreciation	132 052	4 199 842	4 331 894	33 966	4 123 849	4 157 815	3 667 009	3 594 315
Total operating revenues	4 796 680	12 926 326	17 723 006	3 988 262	10 435 451	14 423 713	5 867 202	6 304 813
Total operating expenses	3 911 367	10 644 105	14 555 472	3 353 831	7 274 769	10 628 600	5 557 389	5 858 947
Operating ratio	81.54	82.34	82.13	84.09	69.71	73.69	94.72	92.93
Net operating revenue	885 313	2 282 221	3 167 534	634 431	3 160 682	3 795 113	309 813	445 866
Taxes	390 707	944 481	1 335 188	482 396	1 037 028	1 519 424	985 291	1 011 062
Equipment rents	Dr 420 928	Dr 178 912	Dr 599 840	Dr 337 218	Dr 185 233	Dr 522 451	Dr 958 662	Dr 920 175
Joint facility rents	Cr 40 929	Cr 3 264	Cr 44 193	Cr 54 941	Dr 60 221	Dr 5 280	Dr 233 791	Dr 247 992
Total expenses, taxes and rents	4 682 073	11 764 234	16 446 307	4 118 504	8 557 251	12 675 755	7 735 133	8 038 176
Net railway operating income	114 607	1 162 092	1 276 699	Def 130 242	1 878 200	1 747 958	Def 1 867 931	Def 1 733 363
Other income	55 910	115 825	171 735	29 810	231 023	260 833	250 860	161 992
Fixed charges	398 094	215 159	613 253	162 406	201 435	363 841	1 170 173	1 053 540
Net income	241 430	1 046 731	1 288 161	Def 286 096	1 887 957	1 601 861	Def 2 812 839	Def 2 651 550
FREIGHT SERVICE STATISTICS:								
Revenue tons carried	1 835 385	5 288 692	7 124 077	1 548 695	5 199 874	6 748 569	3 420 177	4 175 393
Freight revenue (Acct.101)	1 667 966	5 221 313	6 889 279	1 609 770	5 224 294	6 834 064	2 803 708	3 039 746
Freight proportion of operating expenses	$1 124 807	$3 562 447	$4 687 254	$1 080 511	$2 818 063	$3 898 574	$1 814 218	$2 183 284
Revenue ton-miles	47 259 205	186 508 658	233 767 863	43 560 368	166 903 024	210 463 392	112 724 517	126 419 931
Net ton-miles	47 354 530	194 986 097	242 340 627	47 073 454	173 691 237	220 764 691	123 511 000	129 428 000
Gross ton-miles (excl.loco.& tender)	128 798 000	*429 506 000	558 304 000	117 280 000	*380 890 000-	498 170 000	286 733 000	290 407 000
Freight train-miles	224 563	598 033	822 596	194 804	401 938	596 742	407 094	445 012
Loaded freight car-miles	2 224 236	6 667 013	8 891 249	1 901 164	6 291 321	8 192 485	4 164 000	3 989 000
Total freight car-miles	3 728 553	11 146 128	14 874 681	3 195 451	10 226 555	13 422 006	7 596 000	7 335 000
Average revenue per ton-mile (cents)	3.529	2.800	2.947	3.695	3.130	3.247	2.487	2.404
Average haul per revenue ton (miles)	25.7	35.3	32.8	28.1	32.1	31.2	33.0	30.3
Gross ton-miles per freight train mile	574	718	679	602	948	835	704	653
Loaded car-miles per freight train mile	9.9	11.2	10.8	9.8	15.7	13.7	10.2	9.0
Total car-miles per freight train mile	16.6	18.6	18.1	16.4	25.4	22.5	18.7	16.5
Freight proportion of operating expenses per freight train mile	$5.01	$5.96	$5.70	$5.55	$7.01	$6.53	$4.46	$4.91
Net ton-miles per loaded car-mile	21.5	29.2	27.3	24.8	27.6	26.9	29.7	32.4
PASSENGER SERVICE STATISTICS:								
Revenue passengers carried	4 812 625	11 518 898	16 331 523	3 566 708	7 013 964	10 580 672	6 011 426	5 650 726
Passenger revenue (Acct.102)	$2 864 017	$7 140 764	$10 004 781	$2 073 622	$4 696 095	$6 769 717	$2 757 921	$2 973 992
Passenger proportion of operating expenses	$2 786 560	$7 081 658	$9 868 218	$2 273 320	$4 456 706	$6 730 026	$3 742 675	$3 675 663
Revenue passenger-miles	180 254 459	302 429 009	482 683 468	142 931 186	228 258 581	371 189 767	273 602 082	235 420 412
Passenger train-miles	1 298 447	3 111 095	4 409 542	1 098 827	2 175 003	3 273 830	2 190 642	1 816 731
Passenger car-miles	6 491 867	15 001 755	21 493 622	5 627 074	10 588 830	16 215 904	9 929 887	9 141 567
Average revenue per passenger mile (cents)	1.589	2.361	2.073	1.451	2.057	1.824	1.008	1.263
Average journey per passenger (miles)	37.5	26.3	29.6	40.1	32.5	35.1	45.5	41.7
Passenger car-miles per train-mile	5.0	4.8	4.9	5.1	4.9	5.0	4.5	5.0
Passenger proportion of operating expenses per passenger train-mile	$2.15	$2.28	$2.24	$2.07	$2.05	$2.06	$1.71	$2.02

* Approximate. Represents figures for Atlantic Division Pennsylvania R.R.

Passenger Service—		
480,216 Train-Miles (engine & crew expenses)	$373,804	
2,229,912 Car-Miles (repairs, train supplies & expenses)	153,641	
Total	$527,445	
Less cost of increased bus service	4,178	523,267
Freight service—		
151,971 Train miles		243,336
Supervision—		
Divisional	$103,002	
General	20,231	123,233
Advertising		19,008
Total		$1,724,632
Less interest, maintenance and taxes on new facilities required, estimated to cost $269,968—		
Interest at 6 percent	$ 16,198	
Maintenance, 3.4 miles of track	4,620	
Taxes	4,000	
	$ 24,818	
Increased joint facility costs	$247,603	272,421
Net Total		$1,452,211

Fixed charges for interest on funded debt for the consolidated company were reduced $160,000 per year by the retirement of $3,200,000 of 5 percent bonds, which were outstanding on facilities abandoned as a result of consolidation.

Subsequent to unification, the passenger operations at Atlantic City were consolidated by building a new station, and abandoning the individual railroad terminals. By this means, annual estimated savings of $117,138 were secured, which are additional to those shown in the estimates of savings in operating costs.

The following is a summary of the estimated annual savings:

Operating costs	$1,452,211
Atlantic City passenger stations	117,138
Total	$1,569,349

In the above, no account is taken for savings incident to value of material salvaged or property released for other purposes.

Potential savings not expressed in monetary terms result from the elimination of 45 grade crossings by trackage abandonment, 20 of which were important and if retained probably would have required grade separation estimated to cost $3,524,945.

Unified operation was effective June 26, 1933. On account of the great loss of traffic, previously noted, there is no valid basis for a comparison of operating and financial results under unified operation with those previously secured.

The West Jersey & Seashore Railroad was leased by the Pennsylvania Railroad Company, July 1, 1930 so that subsequent to 1929 no full year report of West Jersey & Seashore operations was made. For this reason data are not available covering each of the two separately operated properties at the time of their consolidation. However, the accompanying statement shows the financial and operating data covering the two railroads with independent operation during the years 1926 and 1929 and with unified operation during the years 1934 and 1937.

This report is offered as information.

Appendix C

(3) Methods or Formulas for the Solution of Special Problems Relating to More Economical and Efficient Railway Operation

C. H. R. Howe (chairman, subcommittee), J. L. Campbell, S. B. Clement, J. M. Farrin, H. R. Peterson, E. H. Roth, H. F. Schryver, H. A. Shinkle, C. B. Stanton, R. E. Van Atta.

Economic Relation Between Track Structures and Traffic to be Handled

In the previous report on this subject presented at the last convention, and printed in the Proceedings, Vol. 40, page 130, attention was called to the fact that expenditures for roadway and track laying and surfacing labor, apparently were not in accord with the formulas governing allowances for increased or decreased use, as set forth in the Manual, pages 21–9 to 21–14, inclusive. This naturally raises the question as to whether or not the formulas are in need of revision.

After thorough study of the data covering the period 1927 to 1936, inclusive, the committee is of the opinion that the fundamental principles set forth in the formulas are sound and require no revision. There are, however, certain factoral adjustments that should be given consideration in the application of the formulas. Certain changes have taken place in the "Percent Affected by Use" values given in the table shown on pages 21–12 and 21–13 of the Manual. As an illustration, the use of treated ties has materially increased the 30 percent affected by use factor given in the table, while on the other hand measures have been taken to provide greater protection against mechanical wear. Just what the new value should be can not be determined until data are available on the subject. However, the respective percentages for the various accounts have always been subject to adjustments by the individual railways and in no wise affect the principles of the formulas.

It was pointed out in the last year's report that the great reduction in section man-hours that took place from 1927 to 1936 was due principally to improvement in track materials and better methods of handling work. Such changes do not take place abruptly but are gradual variations from year to year; consequently the formulas may be used in adjusting expenditures from year to year with reasonable certitude.

On the other hand, the accumulated changes that take place over a lengthy period of years may be considerable, and vary widely from the figures predicated by formula using the initial year of the period as a base. In such cases the formulas may be used to advantage in determining the economical advantage gained through improvements, for it follows that if the maintenance for a given year on any railway that is kept up to its standard during the long period, requires less labor hours to maintain track than allowed by the formula, using the initial year's labor expenditure as a base; then the difference between the hours allowed by formula and the actual hours spent represents the economic advantage gained. Thus, from the report of last year, using the 18–131-lb. railway group as an example:

1927–8–9 Man-hours per equated mile	3,035
1936 Man-hours per equated mile, by formula	3,010
1936 Man-hours per equated mile, actual	1,564
Difference	1,446

$$\frac{3{,}010 - 1{,}564}{3{,}010} = \frac{1{,}446}{3{,}010} = 48.04 \text{ percent}$$

TABLE D

Section Man Hours per Million Gross Ton-Miles per Equated Mile Reported by Various Railways

Number Assigned to each railway is the same as that given in Table B, Page 131, Bulletin 406.

	Averages for Years 1927-8-9				Averages for Year 1936				
Railway Number and Group	Section Man Hrs. per Eq. Mi. per Annum	Gross Ton Miles per Eq. Mi. per Day	Gross Ton Miles per Eq. Mi. per Annum	Section Man Hrs. per Million G.T.M. per Equated Mi.	Section Man Hrs. per Eq. Mi. per Annum	Gross Ton Miles per Eq. Mi. per Day	Gross Ton Miles per Eq. Mi. per Annum	Section Man Hrs. per Million G.T.M. per Equated Mi.	Section Man Hrs. Percentage Reduction
131-lb. Group									
No. 3.	3,866	15,952	5,827,744	663.38	2,316	11,540	4,223,640	548.34	17.34
" 11	2,240	15,194	5,550,824	403.54	1,042	16,229	5,939,814	175.43	56.53
" 13	3,616	26,083	9,528,902	379.48	2,302	26,679	9,764,514	235.75	37.88
" 15	2,674	19,971	7,296,005	366.50	1,780	22,604	8,273,064	215.16	41.29
" 17	3,921	32,474	11,863,726	330.50	2,325	30,124	11,025,384	210.88	36.19
Group Average	2,908	20,917	7,641,608	380.55	1,597	21,074	7,713,084	207.05	45.59
112-lb. Group									
No. 24	3,852	15,608	5,702,071	675.54	1,652	11,750	4,300,500	384.14	43.14
" 30	2,595	13,420	4,902,729	529.30	1,470	12,857	4,705,662	312.39	40.98
" 36	1,664	9,906	3,618,959	459.80	1,036	9,717	3,556,420	291.30	36.64
" 41	1,528	10,103	3,690,929	413.99	687	9,799	3,586,434	191.56	53.72
Group Average	2,191	11,924	4,356,195	502.96	1,121	11,161	4,084,926	274.35	45.44
100-lb. Group									
No. 48	1,582	4,260	1,556.306	1,016.51	1,913	6,387	2,337,642	818.35	19.49
" 56	2,708	12,018	4,390,536	616.78	1,361	11,626	4,255,116	319.85	48.14
" 59	2,137	10,545	3,852,405	554.72	1,241	9,312	3,408,192	364.12	34.36
" 64	1,393	9,134	3,336,924	417.45	744	8,834	3,233,244	230.11	44.88
Group Average	1,866	9,991	3,650,012	511.23	1,062	9,263	3,390,258	313.25	38.73
90-lb. Group									
No. 79	1,594	5,841	2,133,893	746.99	797	4,017	1,470,222	542.10	27.43
" 81	2,743	11,144	4,071,238	673.75	1,494	9,815	3,592,290	415.89	38.27
" 82	2,357	9,829	3,590,829	656.39	1,274	5,997	2,194,902	580.44	11.57
" 84	2,795	12,362	4,516,209	618.88	1,113	7,179	2,627,514	423.59	31.56
" 87	2,051	10,197	3,725,270	550.56	1,020	8,166	2,988,756	341.28	38.01
Group Average	2,429	10,345	3,779,339	642.70	1,178	7,791	2,851,506	413.12	35.72

TABLE E

Comparison of Actual Section Man Hours per Equated Mile per Year
and Section Man Hours Allocated by Formula

Class and No. of Railways	Section Man Hours per Equated Mile per Year					Actual Percent Reduction per Million G.T.M. per Equated Mi.
	(e) Base Period 1927-8-9	Actual 1936	Percent Reduction of Actual	(E) Allowance by Formula	Percent Reduction from Formula Allowance	
131-lb. - Entire Group (18)	3,035	1,564	48.47	3,010	48.04	46.90
" - No Deferred Maint. (5)	2,908	1,597	45.08	2,918	45.27	45.59
112-lb. - Entire Group (28)	2,362	1,229	47.97	2,285	46.21	41.10
" - No Deferred Maint. (4)	2,191	1,121	48.83	2,138	47.57	45.44
100-lb. - Entire Group (21)	2,103	1,136	45.98	2,032	44.09	38.60
" - No Deferred Maint. (4)	1,866	1,062	43.09	1,814	41.68	38.73
90-lb. - Entire Group (26)	2,196	1,125	48.77	2,076	45.81	36.30
" - No Deferred Maint. (5)	2,429	1,178	51.50	2,198	46.41	35.72

Reduction in section man-hours per million gross tons per equated mile =

$$\frac{403.71 - 214.36}{403.71} = 46.90 \text{ percent}$$

Gross ton-miles per equated mile per annum:

1927–8–9 = 7,517,761
1936 = 7,296,210

From the above figures it will be noted that while the slight reduction in traffic only justified a decrease of 0.824 percent, these railways were able to make a reduction of 48.04 percent in section man-hours.

In the report printed in Vol. 40, page 143, of the Proceedings, it was pointed out that percentages of reduction so obtained, through the use of the formula might be made to serve the purpose of measuring amounts of deferred maintenance. At the time the report was made data were not available to demonstrate this except in a very general way. Since the report was made authentic, information has been published which permits a more accurate analysis of the subject.

The Interstate Commerce Commission has made public data received from the railways in response to questionnaire, "Reports on Deferred Maintenance". In this publication 18 of the railways that reported no deferred maintenance, were included in the list in the tabulation of the committee's report in Bulletin 406. Five were in the 131-lb. group, four in the 112-lb. group, four in the 100-lb. group, and five in the 90-lb. group. Therefore comparisons are possible in all classes.

The committee has segregated these railways from the original lists and obtained new weighted averages for each group. The results are shown in Table D and E.

In connection with the foregoing computations and tabulations, the committee desires to repeat and emphasize the final statement made in the text of last year's report, given on page 144, Proceedings, Vol. 40.

"Reviewing the various items that have been discussed, in connection with the reduction in hours required for track laying and surfacing, it is evident that there is a wide range for variation in the contributory factors in any given case, and that any effective analysis of an individual railroad's results is peculiar to the railway in question."

Conclusion

No revision of the subject matter in the Manual is considered necessary at this time.

This report is presented as information.

Appendix D

(4) Methods for Determining Most Economical Train Length, Considering All Factors Entering Into Transportation Costs

Collaborating with the Operating-Transportation Division

W. B. Irwin (chairman, sub-committee), M. F. Mannion, E. Y. Allen, C. W. Breed, E. K. Eugene, J. M. Farrin, E. E. Kimball, R. S. Marshall, L. S. Rose, E. H. Roth, H. F. Schryver, H. W. Snyder, H. W. Williams.

This subject was assigned to former Committee 21—Economics of Railway Operation, and the first report thereon was published in the Proceedings in 1929. Further reports were published in the Proceedings in 1933, 1934, 1935 and 1938. The several reports having contained many tables and charts pertaining to factors affecting the economical length of trains, an attempt will be made here to summarize the findings in narrative form.

In operating a railroad conditions vary so widely that it is impracticable to adopt a method which can be universally applied for determining the most economical train length. In most cases it is necessary to begin by determining the characteristics of the locomotives involved on the district under consideration, and the committee proceeded on this basis in rendering the following reports:

1929 AREA Proceedings, Vol. 30, page 711

A railroad in the western section of the United States, consisting of seven operating divisions, was taken as a basis for determining:

(a) The track capacity, in train-hours, of a given arrangement of tracks on an engine district, for the purpose of ascertaining the percentage of utilization of the theoretical capacity of the trackage on the district;

(b) The capacity of locomotives, using first a 20-percent coefficient of adhesion between rim of driver and head of rail; second a 25-percent coefficient, with weight on drivers equal to 50 percent of total weight of locomotive, including tender, (also when equal to 60 percent) and tables were prepared showing maximum grades negotiable by freight locomotives with various weights of trains, ranging from 5 to 18 times the weight of locomotive, including tender, and

(c) The weight of train which results in the best performance; graphs of train-hour diagrams disclosed that in the case analyzed the weight of the most economical train was between 11 and 12 times the locomotive weight.

1933 AREA Proceedings, Vol. 34, page 546

The 1933 report consisted chiefly of a discussion of locomotive characteristics. For about 15 years the proportions of locomotives adhered quite generally to Cole's ratios adopted by the manufacturers in 1914. Beginning about 1929, however, a number of changes were made in locomotive design affecting size of fire-box, grate area, type of superheater, and the addition of the feedwater heater and other accessories, also the use of larger tenders, all of which have greatly increased the efficiency of steam locomotives. As a result of these improvements the more modern locomotives are treated as special cases in this report until sufficient data are available to revise Cole's formula.

One of the first steps in such a study is to classify various types of steam locomotives according to their weight on drivers, which for usual types varies from 30 percent to 70 percent of the total weight of locomotive and tender.

The study also discloses that the cylinder horsepower per ton on drivers decreases as the percentage of weight on drivers increases, also the boiler horsepower decreases, but more rapidly than the cylinder horsepower, as the percentage of weight on drivers increases, indicating that the boiler is a limiting factor of steam locomotives. Having established the relationship between horsepower and percentage of weight on drivers, the tonnage rating is readily computed, both maximum tonnage rating and the tonnage rating which will produce the maximum gross ton miles per train hour on various grades for the different classes of locomotives and trains.

To facilitate checking tonnage ratings tables were prepared covering four classes of locomotives, with 30 percent, 35 percent, 40 percent and 45 percent of their weight on drivers for three classes of trains, viz: manifest, coal and ore, and empty trains.

An empirical formula was derived which closely approximates Cole's ratios for the purpose of obtaining a mathematical solution for the maximum gross ton-miles per train hour.

An exhibit regarding locomotive development discusses the fundamental principles of locomotive traction to explain the manner of correlating factors pertaining to motive power, in order to simplify the solution of some of the operating problems depending upon them, accompanied by charts and tables under the headings:

Effect of Power Losses on Tractive Effort
Train Resistance:—Resistance Formula by W. J. Davis, Jr., for locomotives, freight cars, passenger cars, multiple unit cars, and motor cars
Curve and Grade Resistance
Tonnage Rating and Horse Power Rating of Locomotives
Boiler Capacity
Distribution of Locomotive Weights
Characteristics of Steam Locomotives
Speed Factors
Drawbar Pull
Characteristic Speed Tractive Effort Curves
Theoretical Maximum Trailing Ton-Miles per Hour
New Types of Locomotive Designs and Construction
Development of New Formulas

1934 AREA Proceedings, Vol. 35, page 890

The first part of the 1934 report supplements that of 1933 regarding the capacity of steam locomotives. This includes a master chart for obtaining horsepower capacities of typical locomotives from the weight of locomotive and weight on drivers, affording a convenient method of estimating capacity. A form was supplied for calculating the tractive effort and horsepower output at the rims of drivers. These characteristics can be applied to speed-time-energy computations over any profile without the necessity for any separate allowance for weight on drivers, non-driver weight or for freight-train resistance, and the tractive effort at various speeds can be readily computed from this form.

The report includes tables of conditions required to secure maximum gross ton-miles per hour for manifest, coal and ore, and empty trains, with locomotives having from 30 to 60 percent of their total weight on drivers, for speeds varying from 10 to 60 miles per hour on grades ranging from –0.4 to 2.4 percent. A set of tables of anticipated future locomotive designs is also submitted.

The second part of the 1934 report embraces a comparison of freight train and yard performances for the purpose of studying the effects upon yard operation of operating long, heavy road freight trains.

A statement is included showing statistics for freight train and yard performance, supplemented by charts depicting:

Road Performance and Hours Road Time per 100 Train-Miles,
Yard Performance and Switch Locomotive Hours per 100 Train-Miles
Comparison Freight Train and Yard Switching Performance by Years, 1920–1932 inclusive, in Hours per 100,000 Gross Ton-Miles
Comparison Freight Train and Yard Switching Performance, Basis of Train Weight —Average Train Weight Tons—Hours per 100,000 Gross Ton-Miles

It was concluded that the gross ton-mile is the most practical unit for measuring switching service, and that for our purpose it is an unnecessary refinement to adjust reported gross ton-miles for increase in tare weight of freight cars, and for increase in average length of haul in order to have a more accurate measure of the service performed by yard engines. The results obtained from the tables and charts show that in some instances yard-engine hours in freight switching service exceed train hours on the road. It was recognized that this may not be a true measure of yard operations but there is a relationship between yard and road service, as yard performance was found to fluctuate with the volume of traffic in the same manner as did road freight service.

1935 AREA Proceedings, Vol. 36, page 252

The 1935 report supplements the 1933 and 1934 reports on the capacity of steam locomotives by presenting a similar report on oil-electric (Diesel) locomotives and rail cars, portions of the 1934 report being revised and included in the 1935 report to portray the basic similarity between steam and Diesel motive power.

The chief form of difference between steam and Diesel locomotives is in the application of power, making it possible to modify along broad lines the design and construction of Diesel locomotives.

Although we are more concerned with road locomotives in a discussion of the economical train length, it is proper to differentiate between road locomotives, switching locomotives, and rail cars of the Diesel type because larger motors and generators, such as are used in road locomotives, are in general more efficient than smaller ones, and because the power required to operate auxiliaries is a smaller percentage (about 4 percent) of the engine capacity in the case of road power than for smaller power (about 7 percent).

For these reasons it is assumed that nominal horsepower output of road engines equipped with large power units is 78 to 82 percent (including 4 percent for auxiliaries) of the engine capacity, as compared with 73 to 77 percent (including 7 percent for auxiliaries) for switching locomotives and rail cars equipped with smaller power units.

Tables and charts were compiled for computing speed-tractive effort curves for Diesel electric locomotives and rail cars.

1938 AREA Proceedings, Vol. 39, page 533

Reference is made to a study of locomotive capacities by Committee 16 published in AREA Proceedings, Vol. 39, pages 440–472, which was used by Committee 21 as a basis for revised tables published in Vol. 39, pages 539–541, showing the theoretical maximum and most efficient tonnage ratings per ton of locomotive (engine and tender) for various types of steam locomotives on various grades, from –0.4 to 2.4 percent, for weights on drivers varying from 43 to 86 percent of the weight of the engine, for three classes of freight trains, viz:—manifest, coal and ore, and empty trains.

In a typical analysis of freight train operations one of the first steps is to determine the number of locomotives required for a stated volume of traffic. For this purpose there will be required a condensed profile, a track chart and at least the following items of operating data, applicable to the handling in both directions of three classes of traffic, viz:—fast freight, slow freight, and all freight:—

1. Length of engine district—miles
2. Gross ton miles—thousands
3. Gross tons handled
4. Average weight of train—gross tons
5. Number of trains operated
6. Train miles operated
7. Locomotive miles—principal, helper, light, total
8. Minimum road time—hours
9. Average road time—hours
10. Average crew time—hours

11. Locomotive hours—road (subdivided between Transportation department, Mechanical department, Ready before call, and total)
    (a) Number of road locomotives
12. Locomotive hours—helper (subdivided between Transportation department, Mechanical department, Ready before call, and total)
    (a) Number of Helper locomotives

Analysis of these data permits an estimate of crew expense, fuel consumption and maintenance of equipment expense under assumed conditions for comparison with actual conditions.

It is observed that the effect of reducing train tonnage in order to increase speed of freight trains may be practically offest by increased delays for meets resulting from the greater number of trains on the road.

Current Report

Based on the information developed in the reports reviewed above your committee offers the following for adoption and publication in the Manual.

METHODS FOR DETERMINING MOST ECONOMICAL TRAIN LENGTH, CONSIDERING ALL FACTORS ENTERING INTO TRANSPORTATION COSTS

In operating a railroad conditions vary so widely that it is impracticable to adopt a method which can be universally applied for determining the most economical train length. In most cases it is necessary to begin by determining the characteristics of the locomotives involved on the district under consideration. The following tables have been prepared with the object of directing attention to some fundamental factors which govern the physical operation of trains before undertaking economic studies because economic conditions are necessarily fixed by physical limitations.

EXPLANATION OF TABLES

In order to cover a wide variety of conditions, speed-tractive effort and horsepower curves of six modern steam locomotives have been used with three classes of freight trains; namely, manifest trains, coal and ore trains, and empty trains, for the purpose of determining the maximum and most economical tonnage capacities and the corresponding speeds for each class of locomotive and train on various grades from –0.4 percent to 2.4 percent.

The typical locomotives representing each group can be identified by the ratio of the weight on drivers to the weight of engine and by referring to Table 1 in Appendix A of report of Committee 16, Vol. 41 of Proceedings. Some groups contain only one type of locomotive; other groups contain two or more types and some types of locomotives appear in more than one group.

The tonnage capacities given in the table are based on the total weight of engine and tender, that is, the tons and gross ton-miles per hour shown in the tables are to be multiplied by the total weight of the engine and tender, based on typical locomotives.

Thus, in practice, when the group to which the locomotive belongs has been determined from the percentage of weight on drivers, the total weight of the locomotive including tender—which is to be used as the basis of tonnage capacity—is found by dividing the weight on drivers by the constant that applies to the particular group. (Second line of group heading).

The speeds given in the table are based on the normal horsepower capacities also shown for each group.

TABLES SHOWING THEORETICAL MAXIMUM AND MOST EFFICIENT TONNAGE RATINGS PER TON OF LOCOMOTIVE (ENGINE AND TENDER) FOR VARIOUS TYPES OF STEAM LOCOMOTIVES ON VARIOUS GRADES.

PER CENT GRADE	MAXIMUM TONNAGE				MOST EFFICIENT TONNAGE (THEO)									PER CENT GRADE
					MANIFEST TRAINS			COAL&ORE TRAINS			EMPTY TRAINS			
	MPH	MANI- FEST TRAINS	COAL AND ORE TRAINS	EMPTY TRAINS	MPH	TONS	GTM PER HOUR	MPH	TONS	GTM PER HOUR	MPH	TONS	GTM PER HOUR	
- .4	15.84										45.9	11.33	520	- .4
- .3	15.84										44.6	8.81	393	- .3
- .2	15.84				46.9	13.86	650				43.3	7.04	305	- .2
- .1	15.84				45.3	10.05	455	47.5	15.80	750	42.2	5.92	250	- .1
0.0	15.84	21.15	30.90	12.72	44.0	7.95	350	45.8	11.08	507	41.3	5.13	212	0.0
.1	15.84	15.00	19.50	10.08	42.9	6.60	283	44.3	8.35	370	40.3	4.47	180	.1
.2	15.84	11.52	14.12	8.30	41.8	5.55	232	43.1	6.84	295	39.4	4.01	158	.2
.3	15.84	10.29	10.98	7.00	40.8	4.78	195	42.0	5.67	238	38.7	3.67	142	.3
.4	15.84	7.73	8.90	6.03	39.8	4.20	167	40.9	4.84	198	37.9	3.30	125	.4
.5	15.84	6.58	7.45	5.26	38.9	3.73	145	40.0	4.30	172	37.2	3.01	112	.5
.6	15.84	5.70	6.37	4.65	38.1	3.41	130	39.1	3.83	150	36.4	2.72	99	.6
.7	15.84	5.00	5.53	4.14	37.3	3.08	115	38.3	3.47	133	35.7	2.44	87	.7
.8	15.84	4.43	4.87	3.72	36.6	2.76	101	37.5	3.15	118	35.0	2.23	78	.8
.9	15.84	3.97	4.32	3.37	35.8	2.49	89	36.7	2.81	103	34.4	2.09	72	.9
1.0	15.84	3.57	3.87	3.06	35.2	2.30	81	35.9	2.51	90	33.8	1.95	66	1.0
1.2	15.84	2.95	3.17	2.55	34.0	2.00	68	34.5	2.12	73	32.7	1.68	55	1.2
1.4	15.84	2.47	2.64	2.17	32.8	1.74	57	33.3	1.83	61	31.6	1.42	45	1.4
1.6	15.84	2.10	2.23	1.85	31.8	1.45	46	32.2	1.62	52	30.6	1.31	40	1.6
1.8	15.84	1.80	1.91	1.60	30.7	1.34	41	31.1	1.42	44	29.6	1.18	35	1.8
2.0	15.84	1.55	1.64	1.38	29.7	1.18	35	30.1	1.23	37	28.7	1.05	30	2.0
2.2	15.84	1.34	1.42	1.20	28.7	1.05	30	29.1	1.10	32	27.8	.90	25	2.2
2.4	15.84	1.17	1.23	1.04	27.8	.90	25	28.2	.96	27	27.0	.81	22	2.4

Group I—43 percent. Weight on Drivers = .43 x Weight of Engine.
Weight of Engine and Tender = Weight on Drivers/ .24.
Normal Capacity = 40 IHP per Ton on Drivers.

PER CENT GRADE	MAXIMUM TONNAGE				MOST EFFICIENT TONNAGE (THEO)									PER CENT GRADE
					MANIFEST TRAINS			COAL&ORE TRAINS			EMPTY TRAINS			
	MPH	MANI- FEST TRAINS	COAL AND ORE TRAINS	EMPTY TRAINS	MPH	TONS	GTM PER HOUR	MPH	TONS	GTM PER HOUR	MPH	TONS	GTM PER HOUR	
- .4	14.18										42.6	15.85	675	- .4
- .3	14.18										41.5	12.05	500	- .3
- .2	14.18				43.3	19.29	835				40.4	9.60	388	- .2
- .1	14.18				42.0	13.57	570	43.7	22.10	965	39.5	8.02	317	- .1
0.0	14.18	27.40	40.00	16.40	40.8	10.70	426	42.3	14.65	620	38.6	6.73	260	0.0
.1	14.18	19.35	25.10	13.10	39.8	8.52	339	41.0	10.90	447	37.8	5.85	221	.1
.2	14.18	14.88	18.17	10.80	38.8	7.01	272	39.9	8.70	347	37.0	5.14	190	.2
.3	14.18	12.00	14.15	9.13	38.0	6.03	229	38.9	7.10	276	36.3	4.66	169	.3
.4	14.18	10.01	11.50	7.88	37.2	5.32	198	38.0	6.03	229	35.6	4.19	149	.4
.5	14.18	8.55	9.65	6.90	36.4	4.73	172	37.3	5.41	202	34.9	3.78	132	.5
.6	14.18	7.43	8.28	6.12	35.7	4.26	152	36.5	4.77	174	34.3	3.47	119	.6
.7	14.18	6.55	7.22	5.48	35.0	3.83	134	35.8	4.33	155	33.8	3.23	109	.7
.8	14.18	5.84	6.38	4.95	34.4	3.52	121	35.1	3.88	136	33.2	2.95	98	.8
.9	14.18	5.24	5.70	4.49	33.8	3.33	109	34.5	3.57	123	32.7	2.75	90	.9
1.0	14.18	4.75	5.12	4.10	33.2	2.95	98	33.9	3.27	111	32.2	2.55	82	1.0
1.2	14.18	3.95	4.23	3.47	32.2	2.55	82	32.7	2.75	90	31.3	2.24	70	1.2
1.4	14.18	3.36	3.57	2.97	31.3	2.24	70	31.7	2.37	75	30.4	1.94	59	1.4
1.6	14.18	2.89	3.06	2.58	30.4	1.94	59	30.8	2.05	63	29.6	1.69	50	1.6
1.8	14.18	2.51	2.65	2.26	29.5	1.70	50	29.9	1.81	54	28.8	1.53	44	1.8
2.0	14.18	2.20	2.31	1.99	28.7	1.50	43	29.1	1.58	46	28.0	1.36	38	2.0
2.2	14.18	1.94	2.03	1.76	27.9	1.33	37	28.3	1.41	40	27.2	1.21	33	2.2
2.4	14.18	1.72	1.80	1.56	27.2	1.21	33	27.6	1.29	35	26.4	1.06	28	2.4

Group II—53 percent. Weight on Drivers = .53 x Weight of Engine.
Weight of Engine and Tender = Weight on Drivers/ .30.
Normal Capacity = 35.8 IHP per Ton on Drivers.

TABLES SHOWING THEORETICAL MAXIMUM AND MOST EFFICIENT TONNAGE RATINGS PER TON OF LOCOMOTIVE (ENGINE AND TENDER) FOR VARIOUS TYPES OF STEAM LOCOMOTIVES ON VARIOUS GRADES.

	MAXIMUM TONNAGE				MOST EFFICIENT TONNAGE (THEO)									
					MANIFEST TRAINS			COAL&ORE TRAINS			EMPTY TRAINS			
PER CENT GRADE	MPH	MANIFEST TRAINS	COAL AND ORE TRAINS	EMPTY TRAINS	MPH	TONS	GTM PER HOUR	MPH	TONS	GTM PER HOUR	MPH	TONS	GTM PER HOUR	PER CENT GRADE
- .4	12.80										39.3	21.00	825	- .4
- .3	12.80										38.3	14.28	585	- .3
- .2	12.80				39.7	24.20	962				37.4	11.90	445	- .2
- .1	12.80				38.6	16.84	650				36.6	9.84	360	- .1
0.0	12.80	32.80	48.00	19.80	37.7	12.87	485	38.8	17.79	690	35.9	8.47	304	0.0
.1	12.80	23.10	29.95	15.69	36.8	10.22	376	37.7	12.87	485	35.1	7.15	251	.1
.2	12.80	17.74	21.60	12.90	36.0	8.61	310	36.8	10.22	376	34.4	6.22	214	.2
.3	12.80	14.31	16.80	10.93	35.2	7.30	257	36.0	8.61	310	33.8	5.59	189	.3
.4	12.80	11.95	13.70	9.45	34.5	6.32	218	35.3	7.42	262	33.2	5.03	167	.4
.5	12.80	10.21	11.50	8.29	33.8	5.59	189	34.6	6.48	224	32.6	4.54	148	.5
.6	12.80	8.90	9.89	7.37	33.2	5.03	167	33.9	5.66	192	32.1	4.11	132	.6
.7	12.80	7.85	8.64	6.61	32.6	4.54	148	33.3	5.08	169	31.6	3.80	120	.7
.8	12.80	7.01	7.64	5.98	32.1	4.11	132	32.7	4.59	150	31.1	3.51	109	.8
.9	12.80	6.32	6.84	5.44	31.6	3.80	120	32.2	4.22	136	30.6	3.20	98	.9
1.0	12.80	5.73	6.17	4.99	31.1	3.51	109	31.6	3.80	120	30.2	3.01	91	1.0
1.2	12.80	4.80	5.12	4.24	30.2	3.01	91	30.7	3.26	100	29.4	2.69	79	1.2
1.4	12.80	4.09	4.34	3.66	29.4	2.69	79	29.8	2.85	85	28.6	2.34	67	1.4
1.6	12.80	3.55	3.74	3.19	28.6	2.34	67	29.0	2.48	72	27.9	2.11	59	1.6
1.8	12.80	3.10	3.26	2.81	27.9	2.11	59	28.2	2.20	62	27.2	1.84	50	1.8
2.0	12.80	2.74	2.87	2.50	27.2	1.84	50	27.5	1.96	54	26.6	1.69	45	2.0
2.2	12.80	2.43	2.54	2.23	26.6	1.69	45	26.8	1.75	47	26.0	1.54	40	2.2
2.4	12.80	2.17	2.27	2.00	26.0	1.54	40	26.2	1.57	41	25.4	1.38	35	2.4

Group III—61 percent. Weight on Drivers = .61 x Weight of Engine.
Weight of Engine and Tender = Weight on Drivers/ .348.
Normal Capacity = 32.3 IHP per Ton on Drivers.

	MAXIMUM TONNAGE				MOST EFFICIENT TONNAGE (THEO)									
					MANIFEST TRAINS			COAL&ORE TRAINS			EMPTY TRAINS			
PER CENT GRADE	MPH	MANIFEST TRAINS	COAL AND ORE TRAINS	EMPTY TRAINS	MPH	TONS	GTM PER HOUR	MPH	TONS	GTM PER HOUR	MPH	TONS	GTM PER HOUR	PER CENT GRADE
- .4	11.40													- .4
- .3	11.40										34.9	20.34	710	- .3
- .2	11.40										34.0	14.70	500	- .2
- .1	11.40				35.0	21.43	750				33.3	12.00	400	- .1
0.0	11.40	38.50	56.50	23.25	34.2	15.65	535	35.0	21.43	750	32.6	9.88	322	0.0
.1	11.40	27.00	35.95	18.37	33.4	12.36	413	34.2	15.65	535	32.0	8.44	270	.1
.2	11.40	20.68	25.15	15.11	32.7	10.09	330	33.4	12.36	413	31.4	7.26	228	.2
.3	11.40	16.67	19.46	12.80	32.0	8.44	270	32.7	10.09	330	30.9	6.50	201	.3
.4	11.40	13.92	15.95	11.06	31.5	7.46	235	32.0	8.44	270	30.4	5.92	180	.4
.5	11.40	11.91	13.40	9.71	30.9	6.50	201	31.5	7.46	235	29.9	5.35	160	.5
.6	11.40	10.38	11.51	8.64	30.4	5.92	180	30.9	6.50	201	29.5	4.98	147	.6
.7	11.40	9.17	10.08	7.76	29.9	5.35	160	30.4	5.92	180	29.1	4.60	134	.7
.8	11.40	8.20	8.94	7.02	29.4	4.87	143	29.9	5.35	160	28.6	4.16	119	.8
.9	11.40	7.40	8.00	6.41	29.0	4.48	130	29.4	4.87	143	28.2	3.87	109	.9
1.0	11.40	6.72	7.23	5.87	28.6	4.16	119	29.0	4.48	130	27.8	3.60	100	1.0
1.2	11.40	5.65	6.02	5.02	27.8	3.60	100	28.1	3.81	107	27.1	3.17	86	1.2
1.4	11.40	4.84	5.12	4.34	27.0	3.11	84	27.4	3.32	91	26.4	2.80	74	1.4
1.6	11.40	4.21	4.44	3.81	26.4	2.80	74	26.7	2.96	79	25.8	2.52	65	1.6
1.8	11.40	3.70	3.88	3.37	25.8	2.52	65	26.0	2.62	68	25.2	2.22	56	1.8
2.0	11.40	3.28	3.43	3.01	25.2	2.22	56	25.4	2.32	59	24.6	2.03	50	2.0
2.2	11.40	2.93	3.06	2.70	24.6	2.03	50	24.8	2.10	52	24.1	1.87	45	2.2
2.4	11.40	2.63	2.74	2.43	24.1	1.87	45	24.3	1.94	47	23.6	1.70	40	2.4

Group IV—70 percent. Weight on Drivers = .70 x Weight of Engine.
Weight of Engine and Tender = Weight on Drivers/ .402.
Normal Capacity = 28.8 IHP per Ton on Drivers.

Tables Showing Theoretical Maximum and Most Efficient Tonnage Ratings per Ton of Locomotive (Engine and Tender) for Various Types of Steam Locomotives on Various Grades.

PER CENT GRADE	MAXIMUM TONNAGE				MOST EFFICIENT TONNAGE (THEO)									PER CENT GRADE
					MANIFEST TRAINS			COAL&ORE TRAINS			EMPTY TRAINS			
	MPH	MANIFEST TRAINS	COAL AND ORE TRAINS	EMPTY TRAINS	MPH	TONS	GTM PER HOUR	MPH	TONS	GTM PER HOUR	MPH	TONS	GTM PER HOUR	
- .4	10.02													- .4
- .3	10.02										31.2	26.43	825	- .3
- .2	10.02				32.0	43.75	1400				30.4	18.10	550	- .2
- .1	10.02				31.2	26.43	825	32.0	43.75	1400	29.8	14.43	430	- .1
0.0	10.02	44.35	65.25	26.75	30.5	18.86	575	31.1	24.93	775	29.3	12.29	360	0.0
.1	10.02	30.95	40.05	21.10	29.8	14.43	430	30.4	18.10	550	28.7	10.25	294	.1
.2	10.02	23.65	28.75	17.24	29.2	11.98	350	29.8	14.43	430	28.2	8.76	247	.2
.3	10.02	19.05	22.33	14.67	28.7	10.25	294	29.2	11.98	350	27.8	7.52	216	.3
.4	10.02	15.92	20.05	12.68	28.2	8.76	247	28.6	9.93	284	27.3	6.82	186	.4
.5	10.02	13.62	16.60	11.15	27.7	7.54	209	28.2	8.76	247	26.9	6.17	166	.5
.6	10.02	11.88	14.15	9.91	27.3	6.82	186	27.7	7.54	209	26.5	5.66	150	.6
.7	10.02	10.50	12.28	8.92	26.9	6.17	166	27.2	6.65	181	26.1	5.14	134	.7
.8	10.02	9.40	10.82	8.08	26.5	5.66	150	26.8	6.04	162	25.8	4.81	124	.8
.9	10.02	8.49	9.66	7.38	26.1	5.14	134	26.4	5.53	146	25.4	4.33	110	.9
1.0	10.02	7.72	8.28	6.78	25.7	4.67	120	26.1	5.14	134	25.1	4.07	102	1.0
1.2	10.02	6.51	6.92	5.80	25.1	4.07	102	25.4	4.33	110	24.5	3.59	88	1.2
1.4	10.02	5.59	5.91	5.03	24.5	3.59	88	24.7	3.73	92	24.0	3.17	76	1.4
1.6	10.02	4.87	5.12	4.43	23.9	3.14	75	24.1	3.24	78	23.4	2.82	66	1.6
1.8	10.02	4.30	4.50	3.93	23.3	2.79	65	23.6	2.97	70	22.9	2.58	59	1.8
2.0	10.02	3.83	3.99	3.52	22.8	2.50	57	23.1	2.68	62	22.4	2.28	51	2.0
2.2	10.02	3.43	3.57	3.17	22.4	2.28	51	22.6	2.39	54	21.9	2.05	45	2.2
2.4	10.02	3.10	3.21	2.87	21.9	2.05	45	22.1	2.17	48	21.5	1.91	41	2.4

Group V—78 percent. Weight on Drivers = .78 x Weight of Engine.
Weight of Engine and Tender = Weight on Drivers/ .45.
Normal Capacity = 25.3 IHP per Ton on Drivers.

PER CENT GRADE	MAXIMUM TONNAGE				MOST EFFICIENT TONNAGE (THEO)									PER CENT GRADE
					MANIFEST TRAINS			COAL&ORE TRAINS			EMPTY TRAINS			
	MPH	MANIFEST TRAINS	COAL AND ORE TRAINS	EMPTY TRAINS	MPH	TONS	GTM PER HOUR	MPH	TONS	GTM PER HOUR	MPH	TONS	GTM PER HOUR	
- .4	8.60													- .4
- .3	8.60										27.0	29.63	800	- .3
- .2	8.60										26.4	21.00	555	- .2
- .1	8.60				27.1	32.30	875				25.9	16.40	425	- .1
0.0	8.60	50.40	74.40	30.35	26.5	26.05	590	27.0	29.63	800	25.5	13.73	350	0.0
.1	8.60	35.00	45.30	23.88	25.9	16.40	425	26.4	21.00	555	25.1	11.80	296	.1
.2	8.60	26.70	32.40	19.60	25.4	13.20	335	25.9	16.40	425	24.7	10.29	254	.2
.3	8.60	21.50	25.15	16.58	25.0	11.40	285	25.4	13.20	335	24.3	9.01	219	.3
.4	8.60	17.95	20.48	14.33	24.6	9.92	244	25.0	11.40	285	24.0	8.25	198	.4
.5	8.60	15.35	17.20	12.60	24.2	8.72	211	24.5	9.59	235	23.6	7.29	172	.5
.6	8.60	13.30	14.80	11.21	23.8	7.77	185	24.1	8.50	205	23.3	6.65	155	.6
.7	8.60	11.85	12.97	10.08	23.5	7.06	166	23.8	7.77	185	23.0	6.09	140	.7
.8	8.60	10.60	11.51	9.15	23.2	6.47	150	23.4	6.84	160	22.7	5.55	126	.8
.9	8.60	9.60	10.33	8.36	22.8	5.70	130	23.1	6.23	144	22.4	5.09	114	.9
1.0	8.60	8.73	9.35	7.68	22.5	5.20	117	22.8	5.70	130	22.1	4.66	103	1.0
1.2	8.60	7.37	7.83	6.58	22.0	4.55	100	22.2	4.77	106	21.6	4.17	90	1.2
1.4	8.60	6.35	6.70	5.73	21.5	4.05	87	21.7	4.24	92	21.1	3.70	78	1.4
1.6	8.60	5.55	5.82	5.05	21.0	3.57	75	21.2	3.73	79	20.6	3.30	68	1.6
1.8	8.60	4.90	5.12	4.50	20.5	3.17	65	20.7	3.33	69	20.2	2.92	59	1.8
2.0	8.60	4.37	4.56	4.04	20.1	2.89	58	20.3	3.00	61	19.8	2.68	53	2.0
2.2	8.60	3.93	4.09	3.65	19.7	2.59	51	19.9	2.71	54	19.4	2.42	47	2.2
2.4	8.60	3.56	3.69	3.31	19.4	2.42	47	19.5	2.46	48	19.0	2.21	42	2.4

Group VI—86.5 percent. Weight on Drivers = .865 x Weight of Engine.
Weight of Engine and Tender = Weight on Drivers/ .50.
Normal Capacity = 21.7 IHP per Ton on Drivers.

Adjustments.—In the majority of cases it will be found that actual locomotives will not exactly fit into one of the six groups. In these cases, adjustments can be made by interpolating between two groups or prorating.

Likewise, the horsepower capacity of the majority of steam locomotives now operating will be less than shown for the group in which they belong. In these cases the speeds and gross ton-miles per hour obtained from the tables should be adjusted in proportion to the horsepower.

The tractive resistance of locomotives and cars is based on the Davis formulas for 40, 80 and 20-ton cars.

OIL-ELECTRIC (DIESEL) LOCOMOTIVES

A study of oil-electric (Diesel) locomotives and rail cars, discloses a basic similarity between steam and Diesel motive power.

The chief form of difference between steam and Diesel locomotives is in the application of power, making it possible to modify along broad lines the design and construction of Diesel locomotives.

Although we are more concerned with road locomotives in a discussion of the economical train length, it is proper to differentiate between road locomotives, switching locomotives, and rail cars of the Diesel type because larger motors and generators, such as are used in road locomotives, are in general more efficient than small ones, and because the power required to operate auxiliaries is a smaller percentage (about 4 percent) of the engine capacity in the case of road power than for smaller power (about 7 percent).

For these reasons it is assumed that nominal horepower output of road engines equipped with large power units is 78 to 82 percent (including 4 percent for auxiliaries) of the engine capacity, as compared with 73 to 77 percent (including 7 percent for auxiliaries) for switching locomotives and rail cars equipped with smaller power units. (AREA Proceedings, Vol. 36, Page 252).

Until more data on the weight and construction of Diesel freight locomotives are available, preliminary estimates for their use should be based on steam operation; then, when final conditions are established the characteristics of a particular design can be used as a basis for the detailed studies required. Methods for making a direct comparison of Diesel locomotives with steam locomotives are discussed in Appendix A of report of Committee 16, in Vol. 41 of the Proceedings.

ANALYSIS OF FREIGHT TRAIN PERFORMANCE

In a typical analysis of freight train operation, one of the first steps is to determine the number of locomotives required for a stated volume of traffic. For this purpose there will be required a condensed profile, a track chart and at least the following items of operating data, applicable to the handling in both directions of three classes of traffic, viz,—fast freight, slow freight, and all freight:

1. Length of engine district—miles
2. Gross ton miles—thousands
3. Gross tons handled
4. Average weight of train—gross tons
5. Number of trains operated
6. Train miles operated
7. Locomotive miles—principal, helper, light, total
8. Minimum road time—hours
9. Average road time—hours
10. Average crew time—hours

11. Locomotive hours—road (subdivided between Transportation department, Mechanical department, Ready before call, and total)
    (a) Number of road locomotives
12. Locomotive hours—helper (subdivided between Transportation department, Mechanical department, Ready before call, and total)
    (a) Number of Helper locomotives

Analysis of these data permits estimating crew expense, fuel consumption and maintenance of equipment expense under assumed conditions for comparison with actual conditions. It is observed that the effect of reducing train tonnage in order to increase speed of freight trains may be practically offset by increased delays for meets resulting from the greater number of trains on the road. (AREA Proceedings, Vol. 39, page 533). Consideration should also be given to the track capacity in train hours, of a given arrangement of tracks on an operating subdivision for the percentage of utilization of the theoretical capacity of the trackage of the subdivision. (AREA Proceedings, Vol. 32, page 658).

Determination of locomotive characteristics and analysis of freight train performance are important steps in conjunction with the consideration of such factors as volume of traffic to be handled, quality of service required, and limitations of road and equipment, to provide a basis which will serve as a guide for selecting new methods or facilities to meet changing conditions in transportation. On a district composed of undulating grades, the calculations should be checked by dynamometer-car tests.

After due consideration of all these factors the problem of determining the most economical train length from a theoretical standpoint is largely one of comparing locomotive performance under various fixed conditions to decide which of the possible changes in methods of operation is most promising, considered in the light of capital investment involved, additional revenue derived, and the maintenance of a low operating ratio.

Consideration should be given to the following factors affecting economical length of trains, which cannot readily be reduced to mathematical form:

(a) It is recognized that a great deal depends upon the condition of the locomotives and of the track, and the performance of the crews.

(b) The proper location of passing tracks with respect to grade conditions and ease of starting tonnage trains, is of much importance.

(c) The handling of freight trains consisting of from 110 to 150 cars has been demonstrated to be entirely practicable and economical from an operating standpoint but may prove impractical because of other factors, such as traffic considerations, or the inconvenience to the public resulting from delays to highway traffic waiting at grade crossings for the passage of long freight trains.

(d) Retention of rail traffic subject to intensive competition from other transportation agencies necessitates operation of light-tonnage merchandise or general high-class freight trains at high speeds.

(e) Railroads having an unbalanced traffic find it necessary to operate some light tonnage trains in the direction of loaded traffic to provide power for movement of empty cars in the opposite direction during the period when empties are moving in large number for commodities having a seasonal market.

(f) It is the practice of some railroads to reduce their tonnage rating (and, as a consequence, the train length) in order to permit time-freight trains to make their schedule when such trains are running late.

Recommended for adoption and publication in the Manual.

Appendix E

(6) Effect of Inland Waterway Transportation on the Economics of Railway Operation

J. E. Teal (chairman, subcommittee), Richard Brooke, Olive W. Dennis, H. H. Edgerton, R. P. Forsberg, E. E. King, Fred Lavis, Wm. Michel, F. A. Russell, R. E. Van Atta, S. L. Wonson, J. S. Worley.

Foreword

Last year your committee presented its initial report (page 145 of Vol. 40 of the Proceedings), stating that in subsequent reports an effort would be made to analyze specific inland waterway projects and determine, if possible, their economic value, including the volume and the cost of handling their traffic as compared with rail traffic. It is proposed also to evaluate, if possible, the effect of the diversion of rail traffic to the waterways.

The Public Interest

A very large question of public policy affecting the public interest is presented in considering the extent to which funds contributed by the taxpayers of the entire country should be expended by the federal government in the construction and improvement of artificial channels for use by a comparatively few shippers. Are waterways, highways, airways and railways a *social service* to be paid for in large part by general taxation (as are parks, police and schools) or are they, on the other hand, an *economic service* (like electricity, housing and food) to be paid for by the users?

In so far as transportation agencies are used in business for private profit the social service theory does not appear sound. But if, because of other factors affecting national welfare, it is necessary to treat transportation agencies as social services, providing channels of transport at public expense from general tax funds, then the provision should cover all forms of transportation including the railroads.

No commodity can be transported on inland waterways that cannot be transported on the railroads. No transportation service can be furnished by the waterways that cannot be furnished by the railroads. Unless the traffic to be carried exceeds the capacity of the railroads, the diversion of any part of it to other agencies of transportation increases the cost of the remaining railroad traffic. Every ton of freight lost to the railroads means that the unit cost for the tonnage remaining will be greater. Moreover, if entire costs are taken into consideration, measured by the same yardstick by which the costs of rail transportation are measured, the transport costs of inland waterway and highway services exceed those of the railroads.

Therefore, before encouraging through the maintenance of free channels agencies that can exist only by the diversion of traffic from the railroads, consideration should be given to the question of whether the total cost, including that paid directly by the shipper and that paid indirectly by the taxpayer, of moving traffic over these agencies will be less than the cost of rail transportation. If the total costs of providing water transportation on the inland waterways as a whole are taken in consideration including not only the cost of operating the boats and barges but the cost of constructing and maintaining the waterways, the total costs of transportation by water exceed total costs of transportation by rail.

Furthermore, a number of inland waterways are closed for a substantial period each year. The Mississippi river and the Illinois river above St. Louis, the Missouri river between St. Louis and Kansas City, and the New York barge canal are frozen over for several months each year. During these freeze-up periods the railroads are expected to furnish whatever transportation service is needed by the public, regardless of weather conditions. This leads to the question whether any public purpose can be served by encouraging through subsidies, either directly or indirectly, transportation agencies that operate during a portion of the year only, that carry only certain commodities between certain points, and that furnish no service not furnished by the railroads. This is one of the fundamental questions of public policy confronting Congress today.

The railroads now constitute the only agency of transportation that meets the test of general usefulness to the shipping public every day in the year. It is, therefore, unreasonable for the nation to continue to encourage through subsidies, directly or indirectly, every agency of transportation except the railroads, all of them rail competitors, and at the same time to expect the railroads to pay their way in every respect, to contribute large amounts of taxes for the public welfare, and to furnish an adequate system of transportation at all seasons on a diminishing share of the Nation's commerce.

Economics of Inland Waterway Transportation

In considering the devolpment of waterways as an economic question, two phases present themselves for discussion:

1. By what yardstick should inland waterway development as a whole, or the development of any particular scheme of waterways be measured?
2. If the application of such a yardstick indicates that inland waterways should be developed, to what extent should the government undertake to assist in such development?

1. Economic Yardstick

The development of inland waterways is a problem in transportation; therefore, as transportation is fundamental to the economic life of any country, the question should be approached as an economic problem, and not as a political matter. The yardstick to be applied to the transportation of commerce should, therefore, be economic in nature.

The application of economic criteria requires a thorough study and an adequate answer to the following two questions:

1. Are present transportation agencies adequate to the economic needs and future development of the country? If these transportation agencies are adequate, and if they are keeping pace with the future growth and development of commerce, then the provision of additional means of transportation would not be justified unless real economies can be shown.
2. If present transportation agencies are not adequate, then what type of new agency should be developed, taking into consideration:
   (a) Comparative cost of all types of transportation,
   (b) Comparative adequacy, reliability and continuity of service of all types of transportation.

Examining these in detail:

(a) Comparative Cost

The question of cost should include

(1) the capital charges,—all outlays made for construction and for equipment,
(2) all expenditures for maintenance of way and equipment,
(3) depreciation and obsolescence,
(4) the direct cost of transportation itself.

Should it be found that the construction of a new system of inland waterways or an enlargement of any system now in existence can be carried out more cheaply than the extension of railway or highway agencies and give equally good and reliable service, then it would be logical to include waterways in the scheme of future expansion. But in considering the matter of cost, care should be taken to include all the factors of expense, and to give those factors equal weight for each system of transportation.

The effect that bringing a new agency into the field has on the transportation costs of an existing agency must not be overlooked. If the development of waterways affects the traffic density of the railroads, it follows that the rail cost per unit of traffic will increase as traffic declines.

It may be justifiable to construct and operate a new railroad between two points provided the old railroad can be retired. However, if it is impossible to retire the old railroad, the justification of building a new railroad may not be possible. If waterway competition is found to cut into rail traffic, resulting in increasing the rail operating costs per unit, without being able to replace the rail service entirely, then the future development of waterways will not effect a saving in the aggregate transportation bill of the country.

(b) Comparative Adequacy, Reliability and Continuity of Service

In appraising the economic worth of any particular form of transportation, the adequacy, reliability and continuity of the service should be taken into account and compared with the same qualities in other forms of transportation. Climatic interference with service is important, as well as the actual and average speed of the movement; the relative distance between points served; the possibility of obstruction to movement, such as sand bars, floating logs, low water or floods in the rivers, and storms and land slides on the railroads, and other similar problems.

The adequacy of open waterways is usually limited by ice, such restrictions as prevent all-year-round operation on the Great Lakes. Inland waterways, through river or canal, are usually restricted by locks and dams, by widths of channel, by bridges, and by the fact that a mishap to a single tow or barge may block the fairway for days, with no possibility of re-routing other blocked rows by some other line, such as is generally available in the case of a blocked railway.

The problem of regularity on the river is further complicated because it takes longer for the up-stream journey than the down-stream journey. The fluctuating stages of water also affect the dependability of schedules. In this connection, the Inland Waterways Corporation has listed from time to time the difficulties surrounding the operation of the river barges. As an illustration, the annual report of the Inland Waterways Corporation made to the Secretary of War, for the calendar year 1937, makes several citations of unfavorable river conditions on the lower and upper Mississippi, the Illinois river, the Missouri river, and the Warrior river. Among these are:

1. On the lower Mississippi there were established in 1937 three all-time water stage records which increased the difficulty of moving the tonnage:

   (a) The spring flood of 1937;
   (b) The longest continuous period of below-zero river gage at St. Louis, lasting from September 7, 1937, to January 28, 1938;
   (c) The lowest recorded stage that the river has ever reached at St. Louis—5½ ft. on December 13, 1937.

2. On the upper Mississippi five trips were lost in September due to unprecedented low water. On November 17, 1937, the river froze at Rock Island, Ill., the earliest freeze

in 90 years, resulting in a month's delay in getting equipment out of the upper river and into winter quarters.

2. Extent of Government Assistance

Discussing now the second phase of our consideration of the economics of inland waterway transportation, if the application of the economic yardstick indicates that inland waterways should be developed, to what extent should the government undertake to assist in such development?

A bulletin, "Special Series No. 56", issued in 1930 by the Bureau of Railway Economics, entitled "An Economic Survey of Inland Waterway Transportation in the United States," brings out the following salient points.

The only reason for developing inland waterways is to provide a mean of transportation, and unless such a mean is necessary in order to provide adequate transportation, or provide cheaper transportation than existing means, it cannot be justified. It is fallacious to argue that the government is justified in spending huge sums to develop a river, such as, for instance, the Ohio, which parallels existing rail lines more than adequate to handle the traffic at lower costs to the public than the river borne traffic.

While it is true that the rate to the river shipper is slightly lower than the rail rate, this river rate does not reflect the true rate, since it does not include the governmental cost of providing the way for such transportation, a cost which is paid by the general public in the form of taxes. On the other hand, the rail rate reflects all elements of cost, which is the only economically sound basis for figuring rates.

The average freight revenue per ton-mile received by Class I railways in the United States has dropped from 1.275 cents in 1921 to 0.935 cents in 1937. As is shown herein, in many cases the per ton-mile rail rate is lower than the hidden cost to the Government per ton-mile of river-borne traffic without considering the rate paid by the shipper, which must be added to obtain the total cost.

Sound and equitable governmental policy should place all methods of transportation upon an equal footing and only develop inland waterways when and where existing means of transportation are inadequate and such waterways can be profitably and economically used, taking all costs into consideration. Any other policy results in subsidization of the water carrier at the expense of the rail carrier and the general public and is unfair competition.

Ohio River System

Fig. 1 is a map of the Ohio river and its principal tributaries and connecting waterways. This exhibit together with exhibits 2, 3, and 4 has been prepared from information contained in a report prepared by the Corps of Engineers, United States Army, Office of the Division Engineer, Cincinnati, Ohio, dated 1938. As will be noted, the Ohio river is formed by the confluence of the Allegheny and Monongahela rivers at Pittsburgh, Pa., and flows in a general southerly and westwardly direction to its mouth at Cairo, Ill., where it empties into the Mississippi river. The navigable portion of the Ohio and tributaries is indicated by the heavier black lines, and also the approximate location of the many dams and locks are marked either by number or symbol.

Following is a brief description and history relating to the Ohio River system, which are based on a paper entitled "Navigation on the Ohio River," prepared by the Corps of Engineers, U. S. Army, Office of the Division Engineer, Cincinnati, Ohio, also the report of the Chief of Engineers, U. S. Army, for the year 1938. Following this are tabulated statistics showing the investment in the waterways up to June 30, 1938, handled

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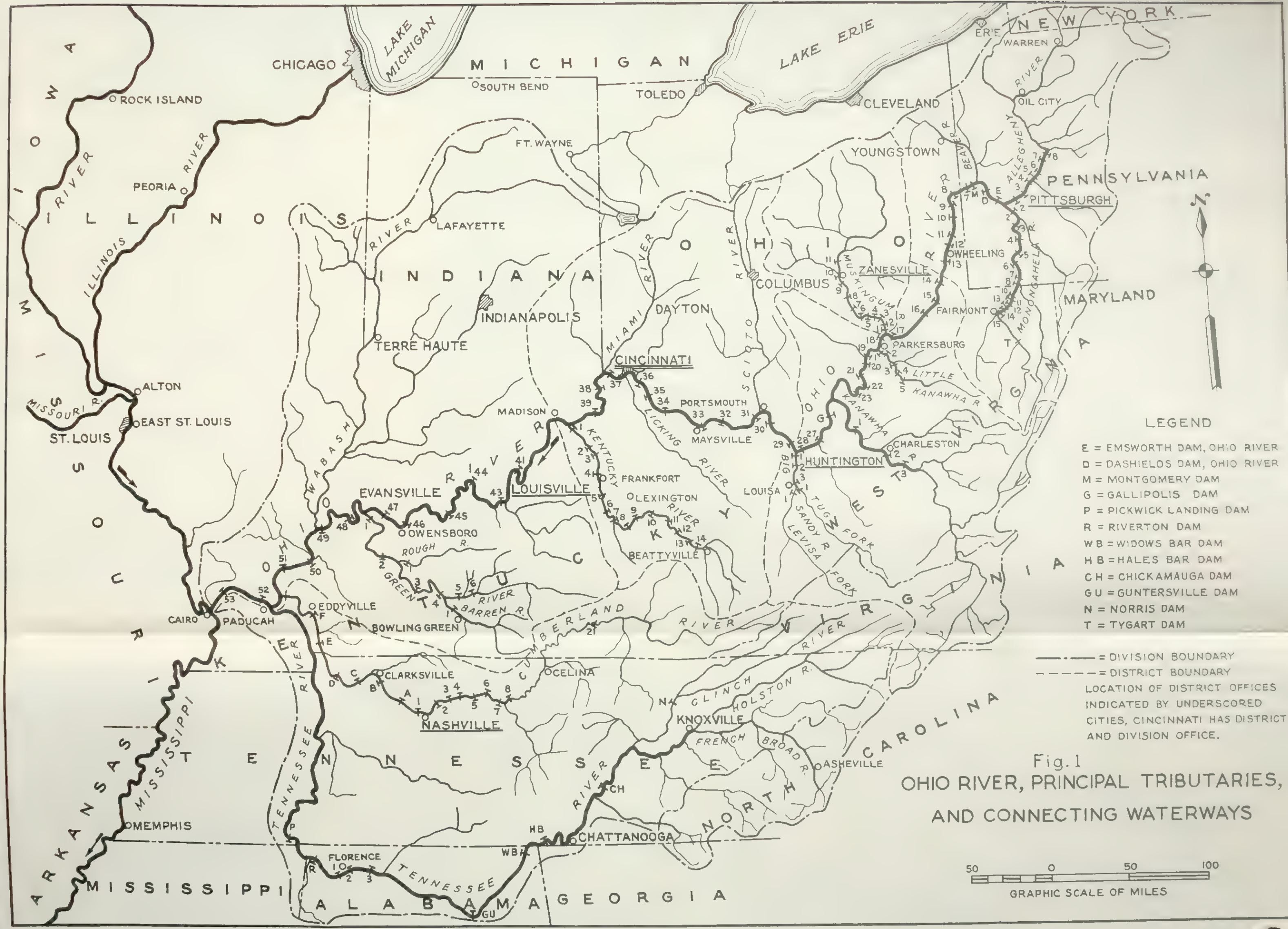


Fig. 1

OHIO RIVER, PRINCIPAL TRIBUTARIES, AND CONNECTING WATERWAYS the cost of maintenance for the year ended June 30, 1938, and the ton-miles handled on each river for the calendar year 1937.

In addition, statistics are presented showing the tons of freight handled on each river for the years 1928 to 1937 inclusive, and their value, together with a statement showing the principal classes of traffic handled.

Ohio River, Pittsburgh, Pa., to Cairo, Ill.

The Ohio River, which is formed by the junction of the Allegheny and Monongahela Rivers at Pittsburgh, runs generally southwesterly to its confluence with the Mississippi River at Cairo, Ill. The watershed comprises portions of the states of New York, Pennsylvania, Maryland, West Virginia, Virginia, North Carolina, Kentucky, Georgia, Alabama, Mississippi, Tennessee, Illinois, Indiana, and Ohio, a drainage area of 203,900 square miles.

Although discovered in 1671, and partially mapped in 1688, it was not until 1700 that traders used its waters to penetrate into the unknown Northwest Territory.

The progress of navigation on the Ohio kept abreast with the growing population. However, the river itself was a fickle servant, sometimes calm, sometimes petulant. It contained many treacherous shoals, etc.

By 1765 canoes (which had been the principal means of transportation) began to give way to the flatboat and the galley bateaux, due to traffic demands. Annual cargoes valued at 50,000 English pounds were marketed to the interior.

By the end of the century the growing demands of traffic called for a type of boat capable of two-way navigation, and the galley keelboat was evolved. These boats were propelled downstream by rowing and drifting, and were poled upstream. Nearly a million dollars worth of goods were transported down the Ohio in 1798, and by 1807, 2,000 flatboats and keelboats arrived annually in New Orleans with cargoes valued at more than $5,000,000.

In 1811 the first steam vessel on the Ohio river appeared. This boat, which was patterned after another deep draft vessel of that time, was found unsuitable for the Ohio River. In 1816 the flatboat hull was adopted to steam power, with all machinery and boiler on deck. A two-decker of the same type was then built, which was destined to revolutionize transportation on inland rivers. The period from 1830 through 1855 was the golden era of the passenger packet. The Ohio River was supplied by lateral feeders, such as roads and tow path canals, and its important tributaries were improved by locks and dams. Packet lines with regular service were formed to serve the rapidly growing river towns.

Subsequent to 1855, however, a variety of factors combined to bankrupt the great steamboat industry. Chief among these was a succession of low water years, which threw traffic into the arms of the growing railroads. The end of the Civil War, however, saw a rennaissance in steamboating. More than 1,000,000 passengers and 2,500,000 tons of freight were now transported annually. Soon, however, a new decline set in, and the advent of the twentieth century, with its demand for speed in passenger transportation, marked almost the exodus of the packet boat.

Prior to this time, however, the barge had been gradually robbing the packets of freight. For decades, basic commodities, such as coal and iron ore, had been transported by fleets of barges. Before this, steamboats had been towing barges astern or lashed to their sides, but now barges were being "pushed" instead of "towed." The newly developed stern-wheeled steamboat could be maneuvered in a hitherto unknown manner through the narrow and obstructed channels of the Ohio.

Under these conditions, the coal traffic of the Ohio by 1850 attained great proportions. The combined volume of coal traffic on the Ohio, Monongahela, and Great Kanawha had reached 10,000,000 tons annually by 1890. A great share of the coal trade was confined to long-distance hauling; however, present day coal tows on the Ohio are confined to relatively short distance hauling. Although coal and coke and sand and gravel traffic constitute a large tonnage item for short distances, iron and steel, oil and gasoline are leading the way in long distance river traffic.

Freight on the Ohio had increased from a total of 6,802,527 tons in 1890 to 14,054,322 tons in 1900; likewise passenger transportation had increased from a total of 416,629 in 1890 to 3,881,588 in 1900.

A new low water cycle commenced, and the railroads, pressing this advantage, obtained much of the traffic that formerly moved via the Ohio, until 1917 saw river transportation at a low ebb.

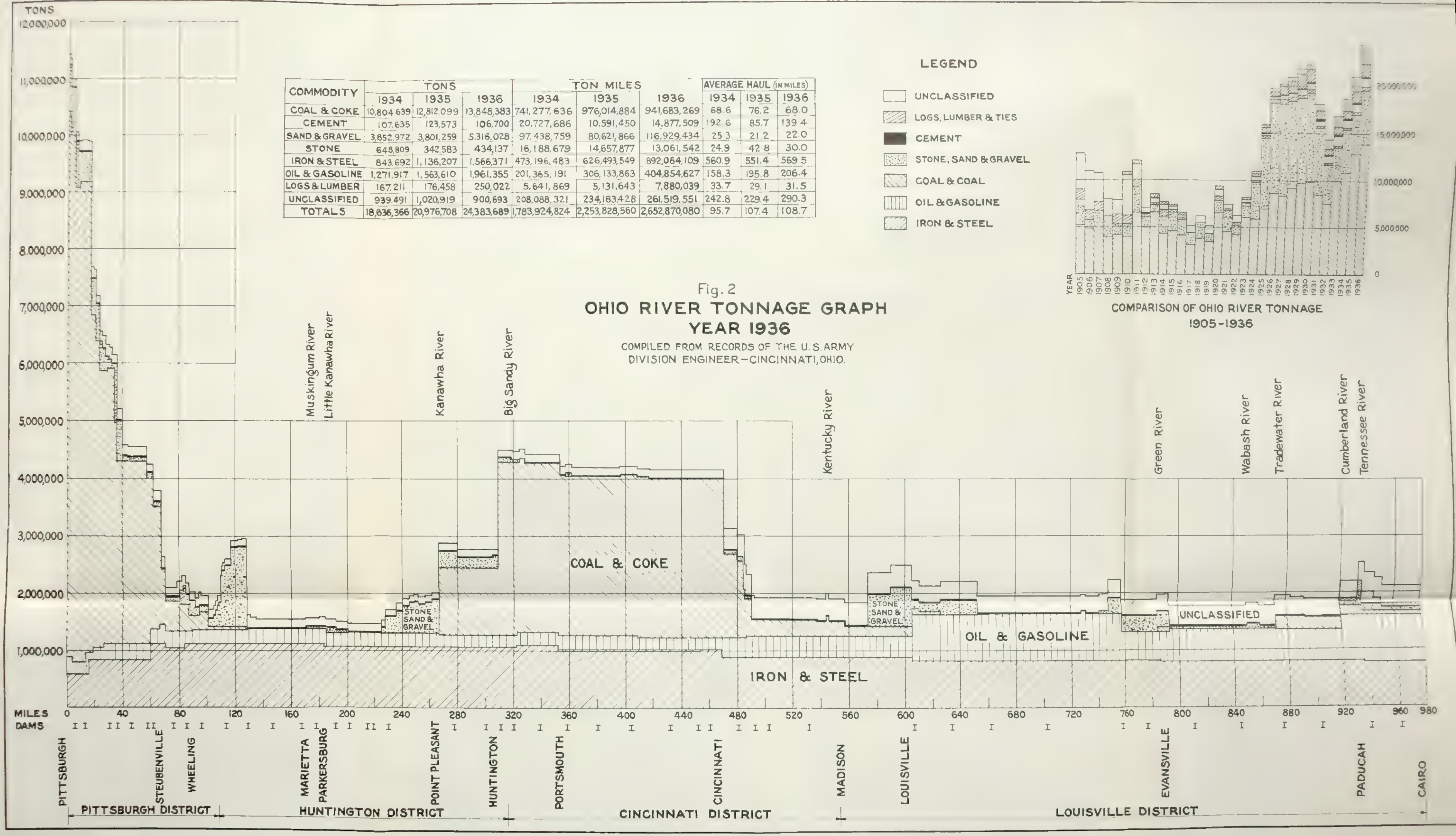
Experience in the upper river, where secure slack water navigation had been achieved on limited stretches by the construction of several locks and dams, led for agitation for the complete canalization of the Ohio, and, finally, Congress voted funds for the Corps of Engineers to complete what they had begun when Davis Island Dam was built in 1885.

After the World War, the use of water transportation for basic, heavy and bulky commodities gradually increased, particularly for long hauls. In 1918, freight traffic began a steady climb to a new height. The steadying effect on commerce of the completed slack-water project on the Ohio in 1929 by a system of low movable type dams is well defined. The economic crash in 1929 and years of recession thereafter caused a decline in freight traffic during 1930–1932 only. From the latter year on, freight traffic had ascended rapidly to new heights, the total Ohio river traffic in 1937 being 23,356,676 tons, valued at $276,701,328 and accounting for 2,671,926,225 ton-miles. This tonnage has become too great for some of the older locks and dams in the upper river, and higher dams with movable crests have been built.

The first lock and dam on the Ohio River was provided for by the River and Harbor Act of March 3, 1879, and other work progressed under acts of September 19, 1890; June 3, 1896; March 3, 1899; June 13, 1902; and March 2, 1907. Existing projects progressed under an act adopted June 25, 1910 and July 18, 1918.

The cost and financial summary for the Ohio River locks and dams and open-channel work construction shows that the cost of work to June 30, 1938, aggregated $140,414,239, and the cost of maintenance to the same date was $61,451,966, making a total cost of permanent work to June 30, 1938, of $201,866,205. The total amount appropriated to June 30, 1938, was $205,767,431.

Fig. 2 shows the tonnage of various commodities transported on the Ohio river between points indicated for the year 1936. It will be noted that the tonnage handled consists chiefly of coal and coke, iron and steel, sand and gravel, and oil and gasoline, and that the largest movements (principally coal and coke) were between Pittsburgh and Steubensville, a distance of 70 miles, and between Huntington and Cincinnati, a distance of 160 miles. The total distance between Pittsburgh and Cairo is 980 miles. This chart also shows in tabulated form the tons and ton-miles hauled during the years 1934, 1935, and 1936, classified between coal and coke, cement, sand and gravel, stone, iron and steel, oil and gasoline, logs and lumber, etc. Out of a total of over 24,000,000 tons handled, coal and coke amounted to 57 percent, sand and gravel 18 percent, iron and steel 6 percent, and oil and gasoline 8 percent. It is also interesting to note that for the year 1936 the average length of haul for coal and coke was 66 miles, sand and gravel 22 miles, iron and steel 569 miles, and oil and gasoline 206 miles, resulting, therefore, in a greater relative percentage in the ton-mileage figures for iron



COMMODITY	TONS			TON MILES			AVERAGE HAUL (IN MILES)		
	1934	1935	1936	1934	1935	1936	1934	1935	1936
COAL & COKE	10,804 639	12,812,099	13,848,383	741, 277, 636	976,014,884	941,683, 269	68.6	76.2	68.0
CEMENT	107,635	123,573	106,700	20,727,686	10.591,450	14,877,509	192 6	85.7	139 4
SAND & GRAVEL	3,852,972	3,801,259	5.316,028	97, 438, 759	80,621, 866	116,929,434	25 3	21.2	22.0
STONE	648,809	342.583	434,137	16, 188, 679	14,657,877	13,061, 542	24.9	42 8	30.0
IRON & STEEL	843,692	1, 136,207	1.566,371	473, 196, 483	626,493,549	892,064, 109	560.9	551.4	569 5
OIL & GASOLINE	1,271,917	1, 563,610	1,961,355	201, 365, 191	306, 133,863	404,854,627	158.3	195.8	206.4
LOGS & LUMBER	167,211	176,458	250,022	5, 641, 869	5, 131,643	7,880,039	33.7	29.1	31.5
UNCLASSIFIED	939,491	1,020,919	900,693	208,088, 321	234,183,428	261, 519, 551	242.8	229.4	290.3
TOTALS	18,636,366	20,976,708	24,383,689	1,783,924,824	2,253,828,560	2,652,870,080	95.7	107.4	108.7

Fig. 2

OHIO RIVER TONNAGE GRAPH
YEAR 1936

COMPILED FROM RECORDS OF THE U. S. ARMY
DIVISION ENGINEER—CINCINNATI, OHIO.

and steel and oil and gasoline. The chart also shows graphically a comparison of the Ohio River tonnage for the years 1905 to 1936. It will be noted that coal and coke, stone, sand and gravel were predominant during the entire period, while iron and steel and oil and gasoline appeared in quantity during the last half of the period.

A study of the location chart in Fig. 2 is of particular interest. Between Pittsburgh and Steubensville the traffic density varied from 11,500,000 tons to about 2,000,000 tons; between Steubensville and Point Pleasant it varied from about 2,900,000 tons to about 1,500,000 tons; between Point Pleasant and Huntington it was about 2,800,000 tons; between Huntington and Cincinnati it varied from 4,500,000 tons to 4,600,000 tons; between Cincinnati and Louisville it varied from 1,900,000 tons to 2,500,000 tons; and between Louisville and Cairo it averaged about 2,000,000 tons.

What effect does this volume of traffic on the Ohio river have on railroad transportation? The answer is obvious: The railroads serving the territory contiguous to the Ohio river as well as to its tributaries would handle a greater volume of traffic if it were not for the improved rivers. It is the opinion of this committee that the railroads with which the rivers compete generally have ample capacity to handle the river traffic; therefore, it follows that if traffic is divided, the resulting unit cost of transportation on the railroads is increased, and the grand total of all transportation by rail and river is greater than if all transportation was handled by the one agency equipped to efficiently and economically handle it.

There is no doubt, in the opinion of this committee, that the railroads serving the territory between Pittsburgh and Cincinnati do have ample capacity to handle all of the traffic now moving by waterway, and if such traffic was handled by rail, the resulting unit cost of transportation would be decreased. Taking a specific illustration: The Chesapeake & Ohio operates a multiple-track railroad between Huntington and Cincinnati. The capacity of this railroad is much greater than the traffic now offered, and if it handled all traffic now moving by water between those points, the unit expense of operation on the railroad would be decreased; applying the increased business theory of expense, it would certainly be less than the cost to the shippers now using the waterway. The traffic would also be handled at much greater speed. A similar illustration (the tonnage, however, does not appear on Fig. 2) is, on the Kanawha river between the head of navigation and Point Pleasant. The river traffic is comparatively large on this section of the Kanawha river. The territory is served by both the Chesapeake & Ohio Railway, which is multiple track, and the New York Central Railroad. Both carriers are amply equipped to handle the traffic with but a relatively small increase in operating expenses. With the added river traffic, the average ton-mile cost on the railroad would be decreased.

Fig. 3 shows the total freight tonnage and passengers transported on the Ohio river for the years 1890 to 1938 inclusive. The freight tonnage value and ton-miles are shown for the years 1915 to 1938 inclusive. It will be interesting to note that the tons hauled increased from about 6,800,000 in 1890 to about 13,200,000 in 1905. Between 1905 and 1923 the business was, generally, declining, with a minimum for the year 1915 of 4,800,000 tons. Beginning with 1923, the tonnage has, generally, been increasing, the maximum being in 1936, when about 24,400,000 tons were hauled. The passengers handled throughout the entire period ranged from a minimum of less than 200,000 in 1917 to a maximum of about 4,700,000 in 1909, the general average being about 1,500,000.

Fig. 4 shows graphically the information shown on Fig. 3 of the Ohio river commerce for the years 1890 to 1938 inclusive. It shows the freight tonnage and number of passengers handled for the entire period, and in addition, the value of the freight and the

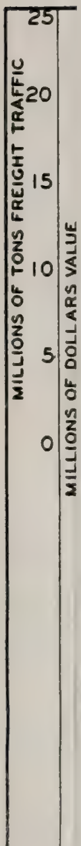
COMMERCIAL STATISTICS – OHIO RIVER

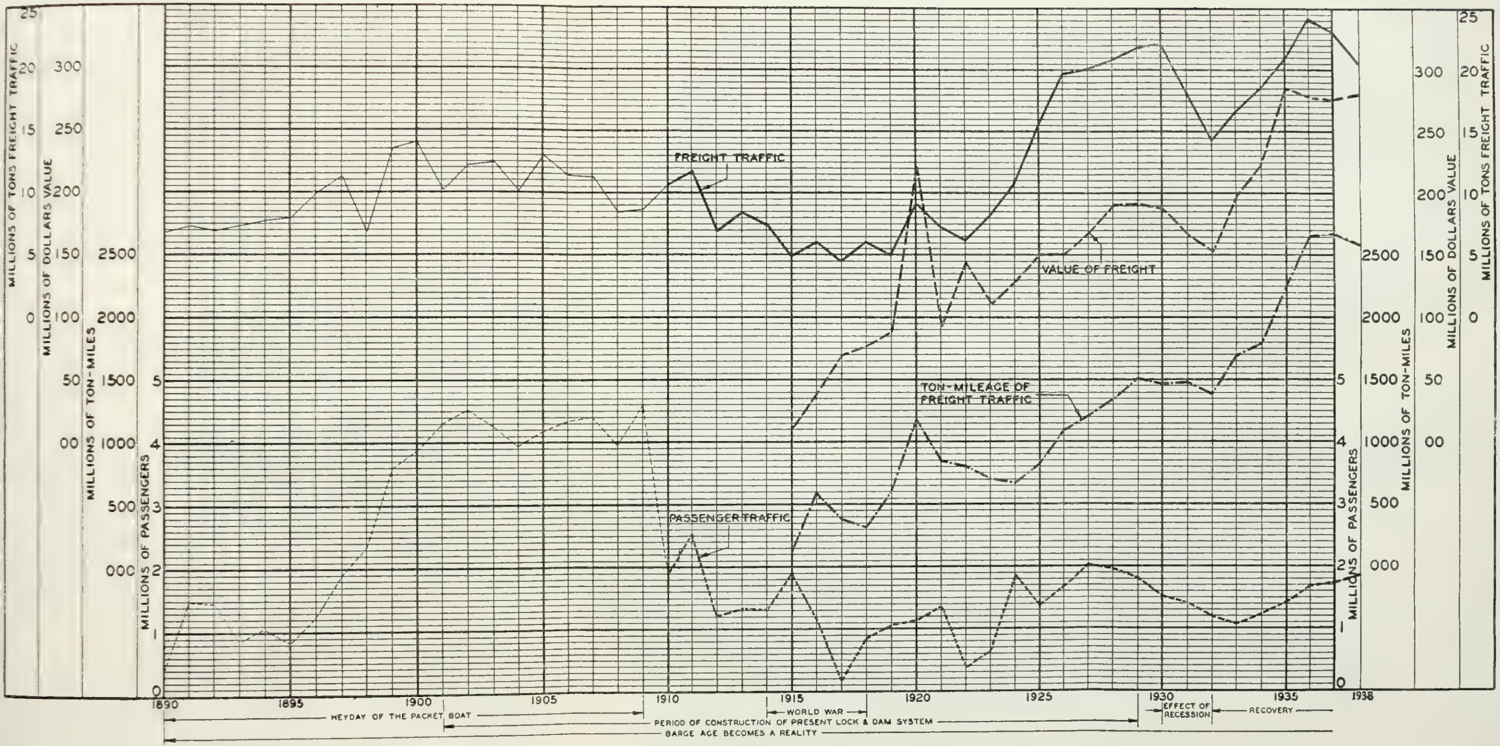
(FERRY TRAFFIC INCLUDED PRIOR TO 1910)

YEAR	TONS HAULED	VALUE	TON-MILES	PASSENGERS
1890	6,802,527			416,629
1891	7,276,516			1,518,167
1892	6,901,186			1,476,363
1893	7,371,804			858,797
1894	7,795,501			1,033,492
1895	7,963,478			806,030
1896	9,914,435			1,223,296
1897	11,265,638			1,914,763
1898	6,756,627			2,335,963
1899	13,529,742			3,612,985
1900	14,054,322			3,881,588
1901	10,064,978			4,304,730
1902	12,202,017			4,517,635
1903	12,499,842			4,286,031
1904	10,142,551			3,951,384
1905	13,163,656			4,193,971
1906	11,427,784			4,349,069
1907	11,306,544			4,414,213
1908	8,498,754			3,960,965
1909	8,676,701			4,671,794
1910	10,760,491			1,877,030
1911	11,771,892			2,523,150
1912	6,998,747			1,203,674
1913	8,412,603			1,320,952
1914	7,589,161			1,307,728
1915	4,814,517	10,636,286	123,224,749	1,919,351
1916	6,044,914	38,773,722	598,383,464	1,188,516
1917	4,598,875	70,510,379	378,490,809	179,399
1918	6,171,412	77,685,322	315,504,354	864,353
1919	5,004,377	88,912,135	604,750,654	1,048,066
1920	9,382,484	223,443,492	1,183,915,493	1,130,112
1921	7,307,880	93,274,814	844,894,606	1,373,854
1922	6,291,826	144,796,250	807,793,106	378,917
1923	8,280,520	110,022,252	708,302,798	622,269
1924	10,866,682	128,356,018	670,486,423	1,882,961
1925	15,737,072	151,622,242	825,496,592	1,374,268
1926	19,754,978	150,086,223	1,101,829,085	1,677,478
1927	20,128,518	168,422,904	1,214,490,565	2,004,513
1928	20,938,267	191,519,168	1,344,687,000	1,990,143
1929	21,955,148	192,308,473	1,512,584,740	1,744,733 E 28,822 R
1930	22,337,434	188,244,870	1,473,926,729	1,486,049 E 40,678 R
1931	18,071,100	166,987,171	1,488,444,936	1,406,817 E 22,934 R
1932	14,316,914	153,756,826	1,392,228,975	1,187,813 E 11,913 R
1933	16,751,034	199,234,780	1,708,422,266	1,045,312 E 22,120 R
1934	18,636,366	224,444,232	1,783,924,624	1,218,904 E 11,816 R
1935	20,976,708	288,402,041	2,253,828,560	1,394,481 E 17,255 R
1936	24,383,689	279,377,371	2,652,870,080	1,682,098 E 6,878 R
1937	23,356,676	276,701,328	2,671,926,225	1,726,098 E 2,441 R
1938	20,587,402	278,394,449	2,578,824,818	1,583,591 E 4,969 R

E = EXCURSION
R = REGULAR

Fig. 3.


MILLIONS OF TONS FREIGHT TRAFFIC
25
20
15
10
5
0
MILLIONS OF DOLLARS VALUE



NOTE: FERRY TRAFFIC INCLUDED PRIOR TO 1910

FIG. 4
GRAPH OF
OHIO RIVER COMMERCE
1890 - 1938

ton-miles for the years 1915 to 1938 inclusive. The exhibit speaks for itself. The increase in freight traffic handled has been very pronounced since about 1922.

Tables 1 to 31 inclusive, following, have been prepared from information contained in the report of the Chief of Engineers, U. S. Army, for the year 1938, and show for the Ohio river and each of its tributaries:

(a) Cost of new work to June 30, 1938;
(b) Total amounts appropriated to June 30, 1938;
(c) Cost of maintenance and operation for the year ended June 30, 1938;
(d) Annual interest on investment, computed at 4 percent;
(e) Annual tax exemption on investment, computed at 0.77 percent ad valorem;
(f) Ton-miles hauled, calendar year 1937;
(g) Total cost borne by the government per ton-mile;
(h) Comparative statement of traffic for the calendar years 1928 to 1937 inclusive;
(i) Classification of freight traffic hauled.

The investment, annual expenses, and ton-mileage figures have been summarized and tabulated in Table 32. Particular attention, however, should be called to the traffic statistics covering the ten-year period, and also the classification of traffic handled on the various rivers involved in the Ohio river system.

TABLE 1

OHIO RIVER—PITTSBURGH, PA., TO CAIRO, ILL.—981 MILES

Cost of new work to 6–30–38		
Locks and dams	$128,157,490	
Open-channel work	12,256,749	
Total investment	$140,414,239	
Cost of maintenance and operation, year ended 6–30–38		
Locks and dams	$ 2,560,663	
Open-channel work	1,403,308	
Total maintenance	$ 3,963,971	$ 3,963,971
Annual interest on investment, computed at 4 percent		5,616,670
Annual tax exemption on investment, computed at 0.77 percent ad valorem		1,081,190
Total annual cost (subsidy to users)		$10,661,831
Ton miles, calendar year 1937—2,671,926,225		
Total cost borne by government per ton-mile		$0.004

TABLE 2

OHIO RIVER

Section included: Pittsburgh, Pa., to Cairo, Ill., 981 miles. Controlling depth: 9 ft. Project depth: 9 ft. Navigation season: Entire year.

Comparative statement of traffic, vessel and rafted:

Calendar Year	*Tons*	*Total Percent*	*Value*
1928	20,938,267	100	$191,519,168
1929	21,955,148	105	192,308,473
1930	22,337,434	107	188,244,870
1931	18,071,100	86	166,987,171
1932	14,316,914	68	153,756,626
1933	16,751,034	80	199,234,780

	Tons	Total Percent	Value
1934	18,636,366	89	$224,444,232
1935	20,976,708	100	286,402,041
1936	24,383,689	116	279,377,371
1937	23,356,676	112	276,701,328

Total ton miles, year 1937: 2,671,926,225

Principal traffic (freight), 1937:

	Tons	Percent of total
Coal and coke	13,419,829	57
Gasoline	1,823,307	8
Sand and gravel	4,842,984	21
Ores, metals and manufacturers of	1,481,262	6
Various	1,789,294	8

Monongahela River, Pennsylvania and West Virginia

This river is formed by the junction of the Tygart and West Fork rivers about one mile south of Fairmont, W. Va., and flows in a northerly direction 128 miles to its junction with the Allegheny river, forming the Ohio river at Pittsburgh, Pa.

Previous improvement of this river by the federal government progressed under the River and Harbor Acts of June 10, 1872, June 3, 1896, and June 4, 1897. The existing project was authorized by Acts of March 3, 1899; June 13, 1902; March 3, 1905; March 2, 1907; March 4, 1913; September 22, 1922; July 3, 1930; January 31, 1931; and June 26, 1934.

A total of $15,839,667 has been expended for new work to June 30, 1938; the cost of maintenance to that date totaled $21,091,008, making a total cost of permanent work to June 30, 1938, of $36,930,675. The total amount appropriated to June 30, 1938, was $37,350,929.

TABLE 3

MONONGAHELA RIVER—FAIRMONT, W. VA., TO PITTSBURGH, PA.—128 MILES

Cost of new work to 6–30–38	$15,839,667	
Cost of maintenance and operation year ended 6–30–38		$ 402,287
Annual interest on investment computed at 4 percent		633,587
Annual tax exemption on investment computed at .077 percent ad valorem		121,965
Total annual cost		$1,157,839

Ton miles 1937: 1,192,903,407

Total cost borne by government per ton mile: $0.0009

TABLE 4

MONONGAHELA RIVER—WEST VIRGINIA AND PENNSYLVANIA

Section included: Pittsburgh, Pa., to Fairmont, W. Va., 128 miles. Controlling depth: Pittsburgh, Pa., to Lock No. 10, 9 ft.; above Lock No. 10, 7 ft. Navigation season: 348 days.

Comparative statement of traffic:

Calendar Year	Tons	Total Percent	Value
1928	27,412,143	100	$170,974,558
1929	28,907,614	105	166,121,576
1930	25,657,054	94	148,322,557
1931	15,948,620	58	74,697,547
1932	9,399,465	34	51,578,027
1933	12,539,764	46	71,391,380

	Tons	Total Percent	Value
1934	14,219,114	52	$67,744,092
1935	17,940,832	65	87,601,507
1936	24,652,144	90	95,628,567
1937	24,927,507	91	100,895,622

Total ton miles per year 1937: 1,192,903,407

Principal traffic (freight) year 1937:

	Tons	Percent of total
Coal and coke	22,281,289	89
Sand and gravel	1,086,221	4
Ores, metals and manufacturers of	999,885	4
Various	560,112	2

Allegheny River, Pennsylvania

The Allegheny river rises in Northern Pennsylvania and flows northwesterly into New York, thence southward to Pittsburgh, Pa., where it joins with the Monongahela river and forms the Ohio. Its length is 325 miles.

The work on this river was authorized under River and Harbor Acts dated August 5, 1886; June 3, 1896; July 25, 1912; July 3, 1930; August 30, 1935; and June 26, 1934.

The cost of new work to June 30, 1938, was $16,957,265, and the cost of maintenance to the same date was $4,949,866, making the total cost of permanent work to June 30, 1938, $21,907,131. The total amount appropriated to June 30, 1938, was $22,679,868.

TABLE 5

ALLEGHENY RIVER—NORTHERN PENNSYLVANIA TO PITTSBURGH—325 MILES

Cost of new work to 6–30–38	$16,957,265	
Costof maintenance and operation year ended 6–30–38		$179,285
Annual interest on investment computed at 4 percent		678,291
Annual tax exemption on investment computed at 0.77 percent ad valorem		130,571
Total annual cost		$988,147
Ton miles 1937: 44,594,095		
Total cost borne by Government per ton mile		$ 0.022

TABLE 6

ALLLEGHENY RIVER—PENNSYLVANIA

Section included: Pittsburgh, Pa., to Riverton, Pa., improved portion, 61 miles. Controlling depth, 8.0 ft. Navigation season: 356 days.

Calendar Year	Tons	Total Percent	Value
1928	3,477,927	100	$ 9,930,209
1929	3,535,978	102	10,665,113
1930	3,180,596	91	12,789,042
1931	2,297,271	66	8,966,002
1932	2,086,205	60	9,777,396
1933	2,745,908	79	10,375,292
1934	2,946,590	85	11,562,385
1935	3,355,865	96	12,945,592
1936	3,424,403	98	12,031,581
1937	3,377,108	97	11,915,791

Total ton miles, year 1937: 44,594,095

Principal traffic (freight), 1937:

	Tons	Percent of total
Coal and coke	1,440,382	43
Sand and gravel	1,600,396	47
Gasoline	161,445	5
Various	174,885	5

Youghiogheny River, Pennsylvania

This river, the principal tributary of the Monongahela, rises in Preston County, W. Va., near the western boundary of Maryland and flows northwestward 123 miles to McKeesport, Pa., where it empties into the Monongahela river 15.5 miles above its mouth.

The improvement of this river progressed under the River and Harbor Acts approved June 25, 1910; January 21, 1927; and July 3, 1930.

The total cost of new work to June 30, 1938, was $47,195, and the cost of maintenance to that date was $27,683, making a total cost of permanent work to June 30, 1938, of $74,877. The amount required to be appropriated for completion of proposed improvements on the Youghiogheny river, exclusive of available funds, has been estimated at $4,197,000. The total amount appropriated to June 30, 1938, was $85,734.

TABLE 7

YOUGHIOGHENY RIVER—PRESTON COUNTY, W. VA., TO MCKEESPORT, PA.—123 MILES

Cost of new work 6–30–38	$47,195	
Cost of maintenance and operation year ended 6–30–38		$ 298
Annual interest on investment computed at 4 percent		1,888
Annual tax exemption on investment computed at 0.77 percent ad valorem		363
Total annual cost		$2,549
Ton miles 1937: 115,517		
Total cost borne by Government per ton mile		$0.022

TABLE 8

YOUGHIOGHENY RIVER—PENNSYLVANIA

Section included: At McKeesport, Pa. Controlling depth, 9.0 ft. Navigation season 357 days.

Comparative statement of traffic:

Calendar Year	Tons	Total Percent	Value
1928	251,358	100	$ 738,334
1929	318,159	127	1,414,648
1930	277,599	110	1,615,935
1931	212,604	85	1,534,616
1932	189,916	76	1,994,165
1933	311,108	124	2,346,524
1934	295,214	117	1,950,262
1935	241,487	96	2,087,906
1936	212,877	85	1,493,723
1937	196,657	78	885,578

Total ton miles, year 1937: 115,517

Principal traffic (freight), 1937:

	Tons	Percent of total
Coal and coke	94,648	48
Sand and gravel	84,356	43
Various	17,653	9

Muskingum River, Ohio

The Muskingum river is formed by the junction of the Walhonding and Tuscarawas river at Cochocton, Ohio, and flows in a southerly direction, emptying into the Ohio river at Marietta, Ohio, 172.2 miles below Pittsburgh, Pa.; it is 112 miles in length and lies entirely in the State of Ohio.

A federal authorization provided for the taking over, restoration, maintenance and operation of state works and plant to provide slackwater navigation between Marietta and Dresden, Ohio, a distance of 93 miles. The existing project was authorized by River and Harbor Acts of August 5, 1886; March 3, 1905; and June 26, 1934.

The cost of new work to June 30, 1938, was $301,723, and the cost of maintenance to that date was $4,259,416, making a total cost of permanent work to June 30, 1938, of $4,561,138. The total amount appropriated to June 30, 1938, was $4,631,667.

TABLE 9

MUSKINGUM RIVER—COCHOCTON, OHIO, TO MARIETTA, OHIO—112 MILES

Cost of new work to 6–30–38	$301,723	
Cost of maintenance and operation year ended 6–30–38		$77,256
Annual interest on investment computed at 4 percent		12,069
Annual tax exemption on investment at 0.77 percent ad valorem		2,323
Total annual cost		$91,648
Ton miles 1937: 4,297,670		
Total cost borne by government per ton-mile		$ 0.021

TABLE 10

MUSKINGUM RIVER—OHIO

Section included: Ohio river to head of pool at Dresden, Ohio. Controlling depth: 6 ft. Project depth: 6 ft. Navigation season: Entire year.

Comparative statement of traffic:

Calendar Year	*Tons*	*Total Percent*	*Value*
1928	527,822	100	$1,179,484
1929	472,942	90	835,073
1930	746,314	141	1,775,903
1931	675,198	128	1,350,885
1932	610,058	116	1,241,856
1933	521,697	99	1,244,586
1934	517,690	98	1,077,803
1935	642,633	122	1,400,930
1936	754,608	143	1,550,062
1937	839,465*	159	1,719,818

Total ton miles year 1937: 4,297,670

Principal traffic (freight) year 1937:

	Tons	*Percent of total*
Coal	726,754	87
Various	112,711	13

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* Includes 801,094 tons which passed only through Locks 9 and 10.

Little Kanawha River, West Virginia

The Little Kanawha river is 160 miles in length and rises on the western slope of Laurel Hill, W. Va., flows in a general northwesterly direction and empties into the Ohio river at Parkersburg, W. Va.

Improvements progressed under the River and Harbor Act approved August 14, 1876. The existing project was authorized by Acts of June 14, 1880; March 3, 1905; and June 26, 1934.

The cost of new work to June 30, 1938, was $470,536, and the cost of maintenance to that date was $721,361, making a total cost of permanent work to June 30, 1938, of $1,191,897. The total amount appropriated to June 30, 1938, was $1,199,845.

TABLE 11

LITTLE KANAWHA RIVER—LAUREL HILL, W. VA., TO PARKERSBURG, W. V.—160 MILES

Cost of new work to 6–30–38	$470,536	
Cost of maintenance and operation year ended 6–30–38		$11,452
Annual interest on investment computed at 4 percent		18,821
Annual tax exemption on investment computed at 0.77 per cent ad valorem		3,623
Total annual cost		$33,896
Ton miles year 1937: 102,366		
Total cost borne by government per ton mile		$ 0.331

TABLE 12

LITTLE KANAWHA RIVER—WEST VIRGINIA

Section included: Ohio river to head of pool, Dam No. 5 at Creston, W. Va. Controlling depth: 4 ft. Project depth: 4 ft. Navigation season: Entire year.

Comparative statement of traffic:

Calendar Year	*Tons*	*Total Percent*	*Value*
1928	132,923	100	$ 4,820,263
1929	280,525	211	5,871,881
1930	260,408	196	4,059,660
1931	103,999	78	2,715,401
1932	107,133	81	2,349,162
1933	81,990	62	2,056,106
1934	78,773	59	1,985,485
1935	92,680	70	1,944,340
1936	40,135	30	1,051,866
1937	45,601*	34	1,232,989

Total ton miles year 1937: 102,366

Principal traffic (freight) year 1937:

	Tons	*Percent of total*
Gasoline	40,640	89
Various	4,961	11

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* Includes 45,596 tons which did not pass above Lock No. 1.

Kanawha River, West Virginia

The Kanawha river is 97 miles in length, and is formed by the junction of the New and Gauley rivers, a short distance above Kanawha Falls, W. Va. It flows in a general northwesterly direction and empties into the Ohio river at Point Pleasant, W. Va.

Previous improvements were authorized by the River and Harbor Act of March 3, 1873, and modified by the River and Harbor Act of March 3, 1875. Present project was authorized by Acts of July 3, 1930; June 26, 1934; and August 30, 1935.

The cost of new work to June 30, 1938, was $25,637,365, and the cost of maintenance to that date was $5,689,639, making a total cost of permanent work to June 30, 1938, of $31,327,004. The total amount appropriated to June 30, 1938, was $32,844,762.

TABLE 13

KANAWHA RIVER—KANAWHA FALLS, W. VA., TO POINT PLEASANT, W. VA.—97 MILES

Cost of new work to 6–30–38	$25,637,365	
Cost of maintenance and operation year ended 6–30–38		$ 156,803
Annual interest on investment computed at 4 percent		1,025,495
Annual tax exemption on investment computed at 0.77 percent ad valorem		197,408
Total annual cost		$1,379,706
Ton miles year 1937: 144,713,616		
Total cost borne by government per ton mile		$ 0.0095

TABLE 14

KANAWHA RIVER—WEST VIRGINIA

Section included: Mouth to head of pool at London Locks and Dam, Mile 90.6 above mouth. Controlling depth: 6 ft. Project depth: 9 ft. from Lock No. 6 to head of navigation; 6 ft. from mouth to Lock No. 6. Navigation season: Entire year.

Comparative statement of traffic:

Calendar Year	*Tons*	*Total Percent*	*Value*
1928	1,595,846	100	$ 7,332,986
1929	1,532,264	96	7,514,796
1930	1,722,351	108	7,351,941
1931	1,867,335	117	9,899,762
1932	1,482,132	93	8,396,921
1933	1,858,638	116	10,521,420
1934	1,786,483	112	9,476,428
1935	2,204,770	138	10,888,631
1936	2,440,586	153	9,607,466
1937	3,176,319	199	11,616,922

Total ton miles year 1937: 144,713,616

Principal traffic (freight) year 1937:

	Tons	*Percent of total*
Coal	2,786,097	88
Various	390,222	12

Big Sandy, Tug, and Levisa Forks Rivers, West Virginia and Kentucky

The Big Sandy river, 27 miles in length, is formed by the junction of the Levisa and Tug forks at Louisa, Ky., flows in a northerly direction, and empties into the Ohio river at Catlettsburg, Ky. Levisa fork, 160 miles in length, rises in southwestern Virginia and flows in a general northerly direction; and Tug fork, 154 miles in length, rises in southwestern West Virginia and flows in a general northwesterly direction.

Previous improvements of these rivers were authorized by the River and Harbor Acts of July 18, 1878, June 14, 1880, and July 13, 1892. Existing project was authorized under River and Harbor Acts of June 14, 1880; July 13, 1892; March 3, 1899; June 13, 1902; March 3, 1905; March 2, 1907; June 25, 1910; and June 26, 1934.

The cost of new work to June 30, 1938, was $1,586,236, and the cost of maintenance to that date was $1,172,646, making a total cost of permanent work to June 30, 1938, of $2,758,882. The total amount appropriated to June 30, 1938, was $2,776,739.

TABLE 15

BIG SANDY RIVER (27 MILES), TUG (154 MILES) AND LEVISA FORKS (160 MILES)

Cost of new work to 6–30–38	$1,586,236	
Cost of maintenance and operation year ended 6–30–38		$ 25,437
Annual interest on investment computed at 4 percent		63,449
Annual tax exemption on investment computed at 0.77 percent ad valorem		12,214
Total annual cost		$101,100
Ton miles 1937: 358,347		
Total cost borne by government per ton mile		$ 0.282

TABLE 16

BIG SANDY RIVER, TUG AND LEVISA FORKS—KENTUCKY AND WEST VIRGINIA

Section included: Ohio river to head of pools on Tug and Levisa Forks. Controlling depth: 6 ft. Project depth: 6 ft. Navigation season: Entire year.

Comparative statement of traffic, vessel and rafted:

Calendar Year	*Tons*	*Total Percent*	*Value*
1928	18,464	100	$ 575,946
1929	30,819	167	687,082
1930	34,456	187	1,131,563
1931	76,217	413	1,582,324
1932	80,111	434	1,274,712
1933	28,652	155	566,316
1934	33,435	181	829,026
1935	41,911	227	803,490
1936	57,858	313	1,400,433
1937	77,006	417	1,938,893

Total ton miles year 1937: 358,347
Principal traffic (freight), 1937

	Tons	*Percent of total*
Gasoline	44,111	57
Various	32,895	43

Kentucky River, Kentucky

The Kentucky river is formed by the confluence of its north and middle forks about four miles east of the town of Beattyville in east central Kentucky, the south fork joining the main stream at that place.

Improvements of this river progressed under the River and Harbor Act of March 3, 1879. Operation and care of the locks and dams were included in the project July 1, 1935, under the provisions of an act approved June 26, 1934.

Cost of new work to June 30, 1938, was $4,176,749, and the cost of maintenance to that date was $6,773,949, making a total cost of permanent work to June 30, 1938, of $10,950,698. The total amount appropriated to June 30, 1938, was $11,129,344.

TABLE 17

KENTUCKY RIVER—KENTUCKY

Cost of new work to 6–30–38	$4,176,749
Cost of maintenance and operation year ended 6–30–38	$246,316
Annual interest on investment computed at 4 percent	167,070
Annual tax exemption on investment computed at 0.77 percent ad valorem	32,161
Total annual cost	$445,547

Ton miles 1937: 3,796,430

Total cost borne by government per ton mile	$ 0.117

TABLE 18

KENTUCKY RIVER—KENTUCKY

Section included: Mouth at Carrolton, Ky., to Beattyville, Ky. Controlling depth: 6 ft. Project depth: 6 ft. Navigation season: January 1 to December 31.

Comparative statement of traffic, vessel and rafted:

Calendar Year	*Tons*	*Total Percent*	*Value*
1928	144,743	100	$ 1,872,823
1929	156,256	108	2,154,573
1930	111,186	77	1,614,422
1931	152,670	105	656,977
1932	227,261	157	578,480
1933	61,155	42	377,550
1934	126,421	87	509,897
1935	149,870	104	498,608
1936	131,427	91	540,234
1937	163,006	113	805,627

Total ton miles year 1937: 3,796,430

Principal traffic (freight), 1937:

	Tons	*Percent of total*
Gasoline	25,543	16
Sand and gravel	119,710	73
Various	17,753	11

Rough River, Kentucky

Rough river—one of the principal tributaries of Green river—lies wholly within the State of Kentucky. It rises in Hardin county, flows westerly 136 miles, and empties into Green river at Livermore, 71 miles from the mouth of that river.

Improvements of this river were authorized by the River and Harbor Acts of September 19, 1890, and June 26, 1934.

Cost of new work to June 30, 1938, was $105,500, and the cost of maintenance to that date was $65,488, making a total cost of permanent work to June 30, 1938, of $170,988. The total amount appropriated to June 30, 1938, was $174,978.

Table 19

Rough River—Hardin County, Ky., to Livermore, Ky.—136 miles

Cost of new work 6-30-38	$105,500	
Cost of maintenance and operation year ended 6-30-38		$1,554
Annual interest on investment computed at 4 percent		4,220
Annual tax exemption on investment computed at 0.77 percent ad valorem		812
Total annual cost		$6,586
Ton miles 1937: 55,566		
Total cost borne by government per ton mile		$0.119

Table 20

Rough River—Kentucky

Section included: Mouth to Hartford, 30 miles. Controlling depth: 4 ft. Project depth: 4 ft. Navigation season: Practically all year.

Comparative statement of traffic:

Calendar Year	*Tons*	*Total Percent*	*Value*
1928	11,772	100	$ 136,330
1929	10,671	91	112,920
1930	10,279	87	156,781
1931	4,734	40	71,010
1932	5,333	45	78,679
1933	5,572	47	83,580
1934	2,848	24	42,720
1935	2,152	18	28,780
1936	1,765	15	31,770
1937	2,297	20	42,217

Total ton miles year 1937: 55,566

Principal traffic (freight) year 1937:

	Tons	*Percent of total*
Logs, rafted	2,117	92
Various	180	8

Green, Barren and Nolin Rivers and Bear Creek, Kentucky

Green River rises in Casey county, Ky., flows in a northwesterly direction 370 miles, and empties into the Ohio river about eight miles above Evansville, Ind.

Barren river rises in Monroe county, Ky., flows in a northwesterly direction 130 miles, and empties into Green river one-half mile above lock No. 4 and 149.5 miles above the mouth of Green river.

Bear creek rises in Grayson county, Ky., flows in a southerly direction 40 miles, and empties into Green river 0.3 mile above new lock No. 5 and 168.4 miles above the mouth of Green river.

Nolin river rises in Larue county, Ky., flows in a southwesterly direction about 105 miles, and empties into the Green river 1.8 miles above lock No. 6 and 183.5 miles above the mouth of Green river.

Existing improvements were authorized by the River and Harbor Acts of August 11, 1888; March 3, 1893; July 13, 1892; June 13, 1902; March 3, 1905; July 3, 1930; June 26, 1934; and August 30, 1935.

Cost of new work to June 30, 1938, was $2,444,769, and the cost of maintenance was $4,059,879, making total cost of permanent work to June 30, 1938, $6,504,648. The total amount appropriated to June 30, 1938, was $6,622,421.

TABLE 21

GREEN, BARREN, AND NOLIN RIVERS AND BEAR CREEK—KENTUCKY

Cost of new work to 6–30–38	$2,444,769	
Cost of maintenance and operation year ended 6–30–38		$ 69,699
Annual interest on investment computed at 4 percent		97,791
Annual tax exemption on investment computed at 0.77 percent ad valorem		18,825
Total annual cost		$186,315
Ton miles 1937: 11,231,120		
Total cost borne by government per ton mile		$ 0.017

TABLE 22

GREEN AND BARREN RIVERS—KENTUCKY

Section included: Green river from mouth to Mammoth cave, 198 miles; Barron river, from mouth to Bowling Green, 30 miles. Controlling depth: 5 ft. Project depth: 5 ft. Navigation season: Practically all year.

Comparative statement of traffic:

Calendar Year	*Tons*	*Total Percent*	*Value*
1928	590,139	100	$ 9,641,088
1929	554,498	94	8,651,044
1930	455,143	77	9,133,048
1931	218,507	37	2,960,003
1932	188,437	32	1,183,706
1933	409,612	69	2,748,022
1934	351,563	60	2,398,099
1935	227,328	39	1,408,348
1936	268,009	45	2,089,170
1937	173,162	29	1,377,499

Total ton miles year 1937: 11,231,120

Principal traffic (freight) year 1937:

	Tons	*Percent of total*
Asphalt	100,000	58
Various	73,162	42

Tradewater River, Kentucky

Tradewater river is a tributary of the Ohio river lying wholly within the State of Kentucky. It rises in Christian county, flows in a northwesterly direction, and empties into the Ohio river, near Caseyville, Ky., at a point 104 miles from the mouth and 77 miles below Evansville, Ind.

Previous improvements were authorized by the River and Harbor Act of March 3, 1881, and the existing project was authorized by an act of July 3, 1930.

Cost of new work to June 30, 1938, was $18,568, and the cost of maintenance was $6,500, making the total cost of permanent work to June 30, 1938, $25,068. The total amount appropriated to June 30, 1938, was $26,568.

Table 23

Tradewater River—Christian County, Ky., to Caseyville, Ky.—104 miles

Cost of new work to 6–30–38	$18,568	
Cost of maintenance and operation year ended 6–30–38		$ 267
Annual interest on investment computed at 4 percent		743
Annual tax exemption on investment computed at 0.77 percent ad valorem		143
Total annual cost		$1,153

Ton miles 1937: 12,639

Total cost borne by government per ton mile	$0.091

Table 24

Tradewater River—Kentucky

Stretch included: Mouth to coal tipple, 3 miles. Controlling depth: 8 ft. at pool stage from mouth to coal tipple, 3 miles upstream. Project depth: 9 ft. at pool stage from mouth to coal tipple, 3 miles upstream. Navigation season: Entire year.

Comparative statement of traffic:

Calendar Year	*Tons*	*Total Percent*	*Value*
1928	2,351	100	$ 6,177
1929	2,056	87	5,625
1930	3,877	165	13,569
1931	1,816	77	4,540
1932	623	27	1,719
1933	637	27	8,571
1934	240	10	1,300
1935	(none reported)		
1936	900	38	2,700
1937	4,213	179	15,519

Total ton miles year 1937: 12,639

Principal traffic (freight) year 1937:

	Tons	*Percent of total*
Coal	3,893	92
Various	320	8

Cumberland River, Tennessee and Kentucky

The Cumberland river is formed by the junction of Poor and Clover forks in Harlan county, Ky., about 687 miles above its mouth, and flows west to Burnside, Ky., from whence it makes a loop into Tennessee, passes Nashville, and returns to Kentucky, emptying into the Ohio near Smithland, Ky.

Previous improvements were authorized by the River and Harbor Acts of July 3, 1832; March 3, 1871; August 14, 1876; March 3, 1881; July 5, 1884; and September 19, 1890. The existing project has progressed under Acts of August 5, 1886; March 2, 1907; March 2, 1919; June 5, 1920; July 3, 1930; and June 26, 1934.

Cost of new work to June 30, 1938, was $9,567,007, and cost of maintenance was $4,220,156, making the total cost of permanent work to June 30, 1938, $13,787,163. The total amount appropriated to June 30, 1938, was $14,029,671.

TABLE 25

CUMBERLAND RIVER—HARLAN COUNTY, KY., TO SMITHLAND, KY.—687 MILES

Cost of new work to 6–30–38	$9,567,007	
Cost of maintenance and operation year ended 6–30–38		$345,382
Annual interest on investment computed at 4 percent		382,680
Annual tax exemption on investment computed at 0.77 percent ad valorem		73,666
Ton miles 1937 Below Nashville	61,804,351	
Ton miles 1937 Above Nashville	13,754,114	
Total annual cost		$801,728
Total	75,558,465	
Total cost borne by government per ton mile		$ 0.011

TABLE 26

CUMBERLAND RIVER—TENNESSEE AND KENTUCKY ABOVE NASHVILLE

Controlling depth: 0-0 to 1 ft. from Granville to Lock 21; Lock 21 to Burnside, 3 ft.; Nashville to Granville, 5 ft. Project depth, 6 ft. Navigation season: From Granville to Lock 21, usually between Jan. 1 and May 31, 3- to 6-ft. navigation, with navigation practically suspended for the remainder of the year. From Nashville to Granville, all-year navigation.

Comparative statement of traffic:

Calendar Year	*Tons*	*Total Percent*	*Value*
1928	474,713	100	$ 2,251,620
1929	255,587	54	1,535,023
1930	260,874	55	1,013,979
1931	311,187	66	592,309
1932	266,376	56	403,130
1933	103,862	22	292,474
1934	114,347	24	159,492
1935	78,428	17	202,894
1936	103,315	22	582,579
1937	308,175	65	870,418

Total ton miles year 1937: 13,754,114

Principal traffic (freight) year 1937:

	Tons	*Percent of total*
Sand and Gravel	268,229	87
Various	39,946	13

TABLE 27

CUMBERLAND RIVER—TENNESSEE AND KENTUCKY BELOW NASHVILLE

Section included: Cumberland river below Nashville, Tenn. Controlling depth: At least 6 ft. Project depth: 6 ft. Navigation season: Entire year.

Comparative statement of traffic:

Calendar Year	*Tons*	*Total Percent*	*Value*
1928	245,685	100	$ 2,148,177
1929	314,649	128	2,573,834
1930	429,792	175	1,523,804
1931	357,235	145	2,041,338
1932	306,903	125	1,552,934
1933	236,224	96	1,121,096
1934	364,048	148	2,330,823
1935	437,378	178	3,922,807
1936	707,198	288	6,147,168
1937	468,881	191	6,883,494

Total ton miles year 1937: 61,804,351

Principal traffic (freight) year 1937:

	Tons	Percent of total
Gasoline	269,083	57
Various	199,798	43

Tennessee River, Tennessee, Alabama and Kentucky

The Tennessee river is formed by the junction of the French Broad and the Holston rivers in eastern Tennessee, 4.4 miles above the Gay Street bridge at Knoxville, flows southwest into northern Alabama, thence in a generally westerly course across northern Alabama, and from the northeast boundary of Mississippi nearly due north across Tennessee and Kentucky, entering the Ohio river at Paducah, 652.1 miles from the junction of the French Broad and Holston rivers.

Previous improvements were authorized by the River and Harbor Acts of August 30, 1852; July 25, 1868; March 3, 1871; June 10, 1872; September 19, 1890; August 18, 1894; March 3, 1899; April 26, 1904; January 7, 1905; March 2, 1907; June 25, 1910; July 25, 1912; July 27, 1916; and March 3, 1925.

Cost of new work to June 30, 1938, was $16,051,575, and cost of maintenance was $6,247,370, making the total cost of permanent work to June 30, 1938, $22,298,945. Total amount appropriated to June 30, 1938, was $22,565,346.

TABLE 28

TENNESSEE RIVER—EASTERN TENNESSEE TO PADUCAH, KY.—652 MILES

Cost of new work to 6–30–38	$16,051,575	
Cost of maintenance and operation year ended 6–30–38		$ 292,631
Annual interest on investment computed at 4 percent		642,063
Annual tax exemption on investment computed at 0.77 percent ad valorem		123,597
Total annual cost		$1,058,291
Ton miles 1937: 55,332,816		
Total cost borne by government per ton mile		$ 0.019

TABLE 29

TENNESSEE RIVER—KNOXVILLE, TENN., TO PADUCAH, KY.

Section included: Length of section, 652.1 miles. Controlling depth. 0.0 ft. above Chattanooga; 6 ft., Chattanooga to Hales Bar lock and dam, 3.5 ft., Hales bar lock and dam to Widows Bar lock and dam; 1.4 ft., Widows Bar lock and dam to General Joe Wheeler dam; 7.4 ft., General Joe Wheeler dam to Wilson dam; 5.6 ft., Wilson dam to Lock and Dam No. 1; 5.5 ft., Lock and Dam No. 1 to Riverton Lock; 6.5 ft. Riverton lock to Paducah, with regulated flow of 15,000 cu. ft. per sec. minimum below Florence; 4.5 ft., Riverton lock to Paducah without regulation. Project depth: 9 ft. Navigation season: 8 months above Chattanooga for 2-ft. draft; 10 months Chattanooga to Guntersville for 3-ft. draft; entire year below Guntersville for 5.6 ft. draft, with minimum 15,000 cu. ft. per sec. regulation below Florence, or 4.5-ft. draft with no regulation.

Comparative statement of traffic:

Calendar Year	*Tons*	*Total Percent*	*Value*
1928	2,172,505	100	$ 7,562,765
1929	2,045,447	94	6,874,451
1930	2,465,215	113	6,044,578
1931	1,244,355	57	2,684,268
1932	749,715	35	1,500,639

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TABLE 31

OHIO RIVER AND TRIBUTARIES

Cost, Maintenance and Operation, unless otherwise noted, based on Report of Chief of Engineers, U. S. Army, for 1938

Waterway (1)	Location (2)	Navigable Length (Miles) (3)	Investment (4)	Annual Cost				Ton Mileage (Thousands) (9)	Cost per Ton Mile Borne by		
				Maintenance (5)	Interest on Investment (6)	Tax Exemption (7)	Total (8)		Government (10)	User* (11)	Total (12)
Ohio river	Pittsburgh to Cairo	981	$140,414,239	$3,963,971	$5,616,670	$1,081,190	$10,661,831	2,671,926	$0.004	$0.004	$0.008
Monongahela river	Fairmont to Pittsburgh	128	15,839,667	402,287	633,587	121,965	1,157,839	1,192,903	0.0009	0.004	0.0049
Allegheny river	Northern Pa. to Pittsburgh	212	16,957,265	179,285	678,291	130,571	988,147	44,594	0.022	0.004	0.026
Youghiogheny river	Preston Co., W. Va., to McKeesport	31	47,195	298	1,888	363	2,549	115	0.022	0.004	0.026
Muskingum river	Coshocton to Marietta	91	301,723	77,256	12,069	2,323	91,648	4,297	0.021	0.004	0.025
Little Kanawha river	Laurel Hill to Parkersburg	122	470,536	11,452	18,821	3,623	33,896	102	0.331	0.004	0.335
Kanawha river	Kanawha Falls to Pt. Pleasant	97	25,637,365	156,803	1,025,495	197,408	1,379,706	144,713	0.0095	0.004	0.0135
Big Sandy river, Tug and Levisa Forks	S. W. Va. and W. Va. to Catlettsburgh	173	1,586,236	25,437	63,449	12,214	101,100	358	0.282	0.004	0.286
Kentucky river	Kentucky	255	4,176,749	246,316	167,070	32,161	445,547	3,796	0.117	0.004	0.121
Rough river	Hardin Co., Ky., to Livermore	29	105,500	1,554	4,220	812	6,586	55	0.119	0.004	0.123
Green, Barren and Nolin rivers and Bear creek	Kentucky and Indiana	248	2,444,769	69,699	97,791	18,825	186,315	11,231	0.017	0.004	0.021
Tradewater river	Christian Co., Ky., to Caseyville	41	18,568	267	743	143	1,153	12	0.091	0.004	0.095
Cumberland river	Harlan Co., Ky., to Smithland	552	9,567,007	345,382	382,680	73,666	801,728	75,558	0.011	0.004	0.015
Tennessee river	Eastern Tenn. to Paducah	652	16,051,575	292,631	642,063	123,597	1,058,291	55,332	0.019	0.004	0.023
Totals			$233,618,394	$5,772,638	$9,344,837	$1,798,861	$16,916,336				

* Estimate based on an approximate contract offer for transporting coal from Huntington, W. Va., to Cincinnati, Ohio, a distance of 165 miles. The average cost per ton mile for handling all commodities, including iron and steel, manufactured and agricultural products and merchandise, would be in excess of four mills. It is obvious that transport costs on the Ohio, Monongahela and Kanawha rivers, with their large tonnage, is substantially less than on the other waterways shown on this sheet.

Calendar Year	*Tons*	*Total Percent*	*Value*
1933	940,223	43	$ 2,237,087
1934	1,494,698	69	3,492,512
1935	1,899,337	87	7,678,919
1936	2,166,397	100	7,789,769
1937	1,377,107	63	9,067,046

Total ton miles year 1937: 55,332,816

Principal traffic (freight) year 1937:

	Tons	*Percent of total*
Gravel[1]	599,066	44
Sand[2]	442,648	32
Various[3]	335,393	24

---

[1] 150,793 tons government material

[2] 76,682 tons government material

[3] 103,650 tons government material

Table 30 shows the investment in the Ohio river and tributaries for navigation purposes up to June 30, 1938, amounting to $233,618,394, and the total amount appropriated as of that date, amounting to $361,885,305. The difference between these amounts. $128,266,911, represents the total amounts expended for maintenance plus a relative unexpended balance for investment. In this connection, the maintenance expenses for the year ended January 30, 1938, amounted to $5,772,638.

TABLE 30

STATEMENT OF INVESTMENT AND TOTAL AMOUNT APPROPRIATED FOR THE OHIO RIVER NAVIGATION SYSTEM TO JUNE 30, 1938

	Investment (new work)	*Total amount appropriated*
Ohio river	$140,414,239	$205,767,431
Monongahela river	15,839,667	37,350,929
Allegheny river	16,957,265	22,679,868
Youghiogheny river	47,195	85,734
Muskingum river	301,723	4,631,667
Little Kanawha river	470,536	1,199,845
Kanawha river	25,637,365	32,844,762
Big Sandy, Tug and Levisa Forks rivers	1,586,236	2,776,739
Kentucky river	4,176,749	11,129,344
Rough river	105,500	174,978
Green, Barren and Nolin Rivers and Bear creek	2,444,769	6,622,421
Tradewater river	18,568	26,568
Cumberland river	9,567,007	14,029,671
Tennessee river	16,051,575	22,565,346
	$233,618,394	$361,885,305

NOTE: Statistics from Report of the Chief of Engineers, U. S. Army, 1938.

Summary

Table 31 summarizes the information covering investment and annual carrying cost in connection with the Ohio River and its tributaries, previously described. The investment and maintenance figures in columns 4 and 5 were taken from the report of the Chief of Engineers, United States Army, for the year 1938. Interest (Column 6) was computed at the rate of 4 percent on the investment and tax exemption (Column 7) was computed at the rate of 0.77 percent, being the approximate percent of investment, corresponding to rates of railway ad valorem taxes to railway investment.

The total ton-mileage figures (Column 9) were also taken from the report of the Chief of Engineers.

Columns 10, 11 and 12 show the cost per ton-mile, divided between that portion borne by the government (taxpayers) and that portion borne by the users of the waterway. The cost borne by the government was calculated by dividing the total annual carrying charge by the total ton-miles. The cost borne by the users is estimated, based on an investigation of the costs for transporting coal from Huntington, W. Va., to Cincinnati, Ohio, on the Ohio river, a distance of 160 miles. This cost was found to be 65 cents for handling coal, which does not include terminal charges amounting to approximately 10 cents per ton at the Huntington tipple, where the coal is loaded into barges, and 35 cents per ton at Cincinnati for unloading, handling and reloading into railroad cars, preparatory to the final switching service to industries. Coal and coke and sand and gravel constitute, by far, the major portion of the tonnage transported on the Ohio, Monongahela and Kanawha rivers, and the cost of transporting this class of tonnage is probably the lowest for any commodity transported on the rivers. It is obvious, therefore, that the average cost of transporting all commodities on the Ohio River and its tributaries, including iron and steel, oil and gasoline, manufactured and agricultural products, as well as merchandise, would be greater.

Column 9 shows the ton-mileage (thousands) of traffic transported on the rivers in this group for the calendar year 1937, the total amounting to over 4,200,000,000 ton-miles. Had this traffic been handled on the railroads, and equating mileage for the shorter distance between points on the basis of 67 percent, the total ton-mileage would be about 2,800,000,000, which at six mills per ton-mile is equivalent to a gross annual revenue loss to the railroads of $16,800,000. In this instance the application of six mills per ton-mile may be slightly lower than the average rail rates for transporting all commodities that are handled on the rivers; however, it is probably conservative, and it will be noted that the total amount just about offsets the annual cost of maintenance, interest on investment and taxes paid or absorbed by the government, as shown in Column 8.

The figures shown in Column 12 represent a conservative estimate of the total over-all cost per ton-mile for transporting all commodities on the rivers. With the exception of the cost on the Monongahela river, which has, by far, the greatest traffic density (89 percent, coal and coke) per ton-mile of route, and the cost on the Ohio river (57 percent, coal and coke), all other costs are materially in excess of 0.935 cents per ton-mile, which was the approximate average rail freight rate on the service for the year 1937. The maximum cost as shown on this statement is on the Little Kanawha river, of 33.5 cents per ton-mile.

New York State Barge Canal

Early History

The State of New York has maintained a system of canals for over a hundred years. During that time the structures of the more important units of this system have undergone three major enlargements, the third and last of which was authorized by the law of April 7, 1903, and produced what is now popularly known as the New York State barge canal. Summarizing briefly the history up to the time of the authorization of the barge canal, the outstanding features are:

1. The canal system of New York State, between 1817 and 1902, included at one time or another 14 units, 12 of which were constructed by the state and two purchased from private companies.

2. These units had a combined length of 940.5 miles and the initial expenditures for construction and purchase, not including enlargements from time to time, was slightly more than $22,500,000.
3. These units were constructed, or purchased, and subsequently improved and maintained out of state funds, derived from public loans, taxation, canal toll and miscellaneous receipts.
4. Five of the 14 units were officially abandoned or not opened to traffic after 1878. These netted a loss of more than $19,000,000., exclusive of interest charges on construction loans.
5. Including interest payments on loans, the canals from inception down to 1902 failed to pay for themselves by approximately $73,000,000.

Development—Barge Canal System

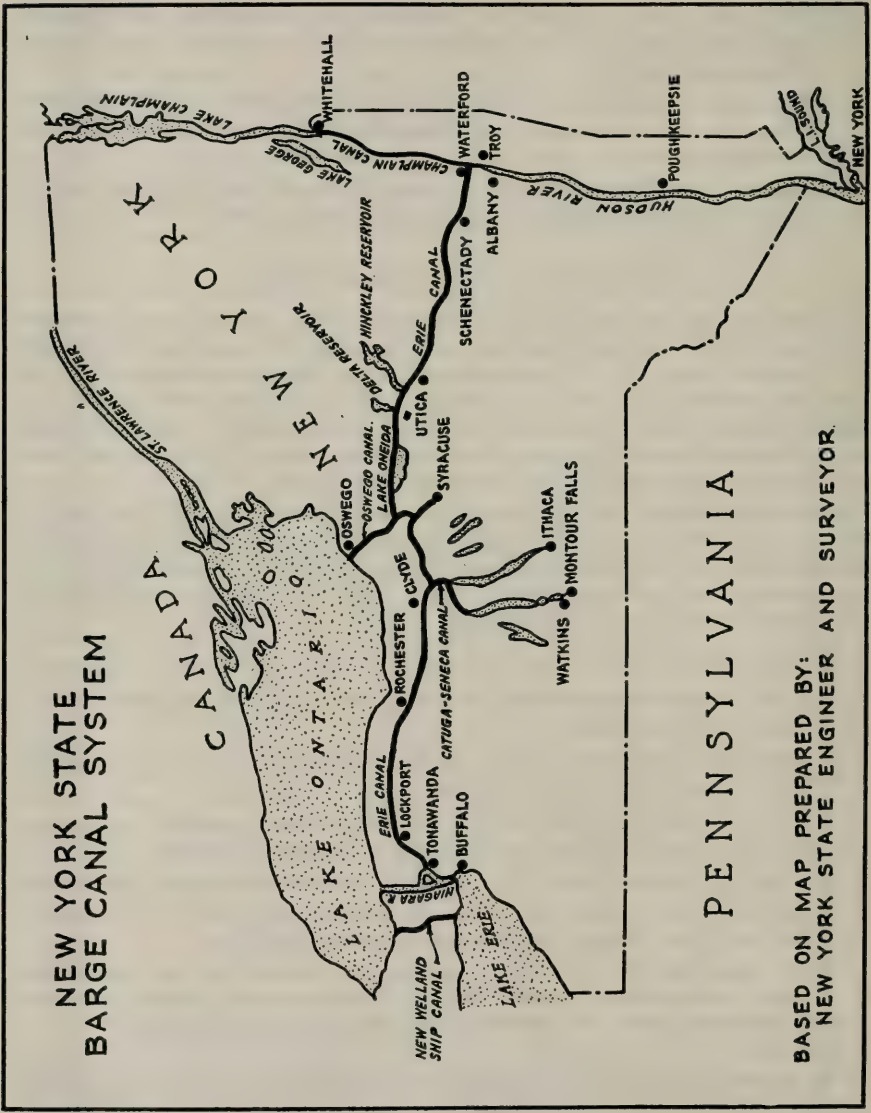
Construction of the New York State barge canal was authorized by a state law dated April 7, 1903. The project covered the enlargement of the existing Erie, Oswego and Champlain canals. In 1909 the enlargement of the Cayuga and Seneca canals was authorized and became a unit of the Barge canal system. The entire project was officially complete in 1918. State bonds aggregating $154,800,000., par value, were issued to cover construction costs, including terminal facilities, and up to 1933 an additional $22,000,000 had been expended on capital construction account.

The system extends from Tonawanda, with connection to Buffalo, via the Niagara river, to Troy, with connection to Albany and New York City, via the Hudson river. Branches extend to Lake Ontario at Oswego, to Lakes Cayuga and Seneca, and to Lake Champlain. The aggregate length of the several canal units totals 525 miles. Figure 1 is a general map of the barge canal system.

In 1926 reports of officials of the state and of the barge canal system indicated that:

1. Traffic on the barge canal had fallen short of expectations and was then only one-tenth of the capacity.
2. The principal reason for the very small use of the canal was ice. The canal is closed by ice for five months each year.
3. Another obstacle was immovable bridges over the canal, permitting an overhead clearance of only 15 ft., which necessitates a special type of boat.
4. At the 66 terminals there were a total of 53 warehouses costing from a few thousand to more than a million and a half dollars each. Many of the terminals had never been used for canal tonnage since they were built.
5. The barge canal had not only too many terminals, but also had too many freight houses, machine shops, derricks, and other terminal facilities, which are seldom, if ever, used, but for which maintenance costs must be paid each year.

At the time the barge canal system was authorized by law in 1903, canals of the state had cost the taxpayers a net amount of $73,000,000 over a period of approximately 85 years. That is, state funds had been drawn upon to that amount in excess of total canal revenues. From 1903 through June, 1933, the aggregate expenditure by the State of New York on the canal system, including all construction costs, maintenance and operation expenses since completion of the canal in 1918, and net interest and other charges on canal bonds, totaled $298,138,034.



NEW YORK STATE BARGE CANAL SYSTEM

BASED ON MAP PREPARED BY: NEW YORK STATE ENGINEER AND SURVEYOR.

Fig. 1.

Federal Aid

Federal assistance to the New York State barge canal was authorized by the Emergency Relief Act of 1935, and up to July 2, 1938, a total of $20,000,000 had been allocated for this purpose. Expenditure of these funds is carried out under the general supervision of the Chief of Engineers, United States Army. The work includes deepening between locks to 14 ft., widening to 104 ft. in cuts and to 200 ft. on curves, and increasing minimum overhead clearance to 20 ft.

Financial and Operating Data

Table 1 is a statement of operating expenses of New York State canals from July 1, 1937, to June 30, 1938. Table 2 is a statement of revenue received for the period December 1, 1937, to November 30, 1938. Table 3 is a tabulation of financial and operating data for the period 1922 to 1937, inclusive, which shows among other things the tons of traffic handled and the cost per ton-mile, for each year.

Up to the close of navigation in 1882, the state collected toll on freight moved over its system of canals. Subsequent to that date, no tolls have been levied. Privately-owned barges move entirely free of charge, except for small licensing and inspection costs, over the waterway. The state pays all canal maintenance and operating costs, which, in the final analysis, must be borne by the general taxpayers of the state.

TABLE 1

STATEMENT OF OPERATING EXPENSES OF NEW YORK STATE CANALS
JULY 1, 1937, TO JUNE 30, 1938

Personal Service		
Personal service, allotted		$ 720,830
Operation of canal system		661,719
Mechanics, laborers and watchmen New York City terminals		30,051
Mechanics, laborers and watchmen upstate terminals		23,691
Prize lock competition		822
Temporary service		2,703
Grain elevator, Brooklyn		87,736
Grain elevator, Oswego		27,867
Power houses		51,036
Public vessel inspection		3,000
		$1,609,455
Maintenance and Operation		
Fuel, light, power and water	$186,185	
Printing and advertising	3,510	
Equipment supplies and materials	56,520	
Traveling expenses	59,301	
Communication	15,778	
Fixed charges and contributions	4,270	
Towing	6,564	
Maintenance of power houses	5,283	
Maintenance and repairs, including dredging and painting	609,814	947,225
Total		2,556,680
Construction or Permanent Betterments		
Removal, repair and reconstruction of bridges, old canal system		7,424
Grand total		$2,564,104

Note: *Source*—Annual report of Superintendent Public Works, Albany, N. Y., for 1938.

TABLE 3

NEW YORK STATE BARGE CANAL

FINANCIAL AND OPERATING DATA - 1922-1937

	Freight Traffic a				Transportation Cost Per Ton-Mile				
Year	Tons (2000 lbs.)	Ton-Miles	Cost of construction b	Annual Operating & Maintenance expenses c	Carrying charge on construction cost at 4 per cent	Carrying charge per ton-mile of freight handled (Mills)	Operating & Maintenance expenses per ton-Mile (Mills)	Boatmen's charge for conveyance per ton-Mile (estimated) (Mills)	Total transporta - tion cost per ton-mile (Mills)
1922	1,873,434	362,442,277	$164,258,545	$2,643,190	$6,570,342	18.13	7.29	4.50	29.92
1923	2,006,284	405,925,906	167,424,182	3,303,331	6,696,967	16.50	8.14	4.50	29.14
1924	2,032,317	448,399,607	170,053,798	3,590,219	6,802,152	15.17	8.01	4.50	27.68
1925	2,344,013	543,860,257	173,611,913	3,184,969	6,944,477	12.77	5.86	4.50	23.13
1926	2,369,367	552,208,134	174,859,957	3,578,200	6,994,398	12.67	6.48	4.50	23.65
1927	2,581,892	581,832,903	175,653,707	4,135,250	7,026,148	12.08	7.11	4.50	23.69
1928	3,089,998	741,878,620	175,817,717	4,100,716	7,034,869	9.48	5.53	4.50	19.51
1929	2,876,160	715,551,472	176,221,141	3,621,076	7,048,846	9.85	5.06	4.50	19.41
1930	3,605,457	922,933,819	176,655,250	3,591,434	7,066,210	7.66	3.89	4.50	16.05
1931	3,722,012	1,358,048,539	176,747,842	3,593,906	7,069,914	5.21	2.65	4.50	12.36
1932	3,643,433	919,298,813	176,762,327	3,014,511	7,070,493	7.69	3.28	4.50	15.47
1933	4,074,002	1,034,026,861	176,778,411	2,788,432	7,071,136	6.84	2.70	4.50	14.04
1934	4,142,728	1,022,900,693	176,805,019	2,732,392	7,072,201	6.91	2.67	4.50	14.08
1935	4,489,172	1,095,460,213	176,837,824	2,908,190	7,073,513	6.46	2.65	4.50	13.61
1936	5,014,206	1,167,591,310	176,848,897	2,465,919	7,073,956	6.06	2.11	4.50	12.67
1937	5,010,464	1,095,517,270	176,878,267	2,493,292	7,075,131	6.46	2.28	4.50	13.24

NOTE: SOURCE - Bureau of Economics, A.A.R.

a - Data for calendar years.
b - Capital cost from April 7, 1903 to July 1st of each year.
c - Fiscal Years ending June 30th.

TABLE 2

STATEMENT OF REVENUES RECEIVED BY THE COMMISSIONER OF CANALS AND WATERWAYS BETWEEN DECEMBER 1, 1937 AND NOVEMBER 30, 1938

Revenue from use of barge canal terminals	$ 83,266
Revenue from water power	334,716
Revenue from use of canal waters	7,647
Revenue from ice privileges	215
Revenue from rentals other than terminals	39,375
Revenue from sales of sand, gravel, etc.	4,905
Miscellaneous revenue	4.046
Revenue from licenses and inspection of vessels	1,784
Revenue from the operation of grain elevators for calendar year 1938	212,149
Total	$688,103

Note: *Source*—Annual report of Superintendent Public Works, Albany, N. Y., for 1938.

The Proposed Lake Erie & Ohio River Canal

Historical

The idea of connecting Lake Erie and the Ohio river with an artificial waterway has been advocated from time to time since the beginning of the last century.

Between 1830 and 1840, a number of towpath canals connecting these waters were constructed and placed in operation. One of these extended from Cincinnati, Ohio to Toledo via the Miami river. Another extended from Portsmouth, Ohio, up to the Scioto river through Columbus, and thence to Lake Erie. A third followed the Muskingum and Cuyahoga rivers. The most important of all, however, was the Pennsylvania-Erie canal, which extended from Beaver, Pa., on the Ohio river, up the Beaver and Shenango rivers, and thence across the divide and down Conneaut creek, and thence parallel with Lake Erie to Erie harbor. This canal, which was completed by the Commonwealth of Pennsylvania about 1840, was sold to private interests in 1843, and remained in operation until a few years after the Civil War, being finally abandoned in 1871.

Chief of Engineers Wilson, United States Army, made a study of a proposed route for a barge canal from Cincinnati to Toledo via the Miami river, and in his annual report, dated February 3, 1881, estimated the cost thereof at $28,557,173. He made no recommendation either for or against its construction.

In 1889, a committee was appointed by the governor of Pennsylvania, in accordance with the terms of a joint resolution of the General Assembly, appropriating $10,000 for the investigation of the feasibility of connecting Lake Erie and the Ohio river by a canal. The committee reported favorably on a route which followed the Beaver and Shenango rivers to a point near Greenville, Pa., and thence overland to Conneaut, Ohio, on Lake Erie. The estimated cost amounted to approximately $26,000,000. No action was taken by the General Assembly on this report.

The Chamber of Commerce of Pittsburgh became interested in the canal project in 1894–1895, and appointed a provisional ship canal committee. This committee raised and expended $50.000 in making a survey along the Beaver and Mahoning rivers to Niles, Ohio; thence via Mosquito creek and finally overland to Ashtabula, Ohio. Nothing resulted from this investigation.

On February 12, 1896, Chief of Engineers Chittenden, United States Army, in his annual report, covered three proposed routes for a connecting waterway, namely, Marietta to Cleveland, Portsmouth to Sandusky, and Cincinnati to Toledo. In each case the report was unfavorable to the construction of a canal.

The so-called Powell report of the United States engineers, under date of November 25, 1898, which contained a report on the Allegheny river-French creek route, was unfavorable to the construction of a waterway by that route.

In 1905, the matter was taken up by the Merchants and Manufacturers Association of Pittsburgh with the result that the Lake Erie and Ohio River Ship Canal Company was organized to construct and operate a canal. Charters were obtained in both Pennsylvania and Ohio, and later a national charter was procured. The company expended $60,000 for surveys and investigations, but private capital was apparently not available and the matter was dropped.

In December, 1910, the Lake Erie and Ohio River Canal Association was formed for the purpose of advocating the construction of a canal via the Beaver and Mahoning rivers, and thence to Lake Erie. Funds were to be obtained from the counties bordering on the canal and the waterways connecting with it, from the states of Pennsylvania, Ohio and West Virginia, and from the national government. As a result of the activities of the association, an act was passed by the Pennsylvania legislature on June 27, 1913, appropriating $150,000 for making surveys and estimates. Enabling legislation was also passed in Ohio and West Virginia. Surveys, plans and estimates were made, but no further action was taken. However, the act of the Pennsylvania legislature provided for the appointment of a Lake Erie and Ohio River Canal Board. The board was appointed May 27, 1914. Its chief engineer was George M. Lehman.

On June 8, 1911, Col. H. C. Newcomer reported on a preliminary examination of a proposed route from Beaver to Ashtabula, and in 1912 the National Waterways Commission, after receiving a favorable report from General W. H. Bixby, chief of engineers of the United States Army, approved the construction of a canal via Beaver and Mahoning rivers, Mosquito creek, and thence to Lake Erie.

The second Lake Erie and Ohio River Canal Board of Pennsylvania was appointed by the governor of the state in 1915. This board, while making a favorable report in June, 1917, for a proposed canal from the mouth of the Beaver to the mouth of Indian creek on Lake Erie, did not outline a definite plan of financing.

In the River and Harbor Act passed by Congress, March 2, 1919, the secretary of war was authorized to make surveys of various routes for a canal connecting the Ohio river with Lake Erie.

A Special Board of United States Army Engineers, on May 7, 1921, made a preliminary examination report, known as the Judson report, on various canal routes, and recommended a survey of the Beaver-Mahoning route from the Ohio river to Ashtabula on Lake Erie.

The River and Harbor Act of September 22, 1922, authorized the secretary of war to make surveys of the Allegheny river-French creek route. In the same year the Board of Engineers for Rivers and Harbors, after reviewing the report of the special board above mentioned, recommended more detailed surveys of various routes.

Colonel C. W. Kutz made a preliminary examination of the French creek route and his report of November 17, 1923, was unfavorable to the construction of a canal by that route.

On March 19, 1925, Colonel Kutz reported on the three other proposed routes, namely, the Pittsburgh-Ashtabula, the Portsmouth-Sandusky, and the Cincinnati-Toledo routes. In each case the report was unfavorable toward the construction of a waterway.

On December 30, 1930, the Board of Engineers for Rivers and Harbors, in accordance with the River and Harbor Act of July 3, 1930, authorized surveys to be made for the proposed canalization of Beaver, Mahoning and Shenango rivers. After a study of over two years, Major W. D. Styer, district engineer at Pittsburgh, in his report of

June 27, 1933, concluded that there was no justification for the canalization of these rivers, and recommended that the government not undertake the proposed construction. Lt. Colonel R. C. Moore, acting division engineer, concurred in Major Styer's findings. However, the Chief of Engineers, Major General E. M. Markham, following the recommendations of the Board of Engineers for Rivers and Harbors, disagreed with the district engineer and the division engineer and recommended that a canal be constructed from Beaver, Pa., up the Beaver and Mahoning rivers to Struthers, Ohio, just east of Youngstown at an estimated cost of $47,000,000. This was the so-called "dead-end" canal. A hearing was held on this project before the Senate Committee on Interstate Commerce in May, 1935, and the improvement of the Beaver and Mahoning rivers was authorized in the River and Harbor Act approved August 30, 1935, as follows:

"Beaver and Mahoning rivers, Pennsylvania and Ohio, of the width and depth provided in House Document No. 277, Seventy-third Congress, as a federal project, and to continue to Lake Erie at or near Ashtabula, Ohio, subject to the final approval of the whole project from the Ohio river to Lake Erie by the Board of Engineers for Rivers and Harbors."

In the meantime, on May 12, 1933, the chief of engineers instructed the district engineer at Pittsburgh, Major W. D. Styer, to make new surveys on the four alternate routes. Major Styer submitted his report on May 31, 1934, and recommended the construction of a canal via Beaver and Mahoning rivers, Mosquito creek and thence to Lake Erie. In a revised report, dated December 26, 1935, he recommended a change in the proposed location of the canal at the north end. The proposed route, as revised, followed the Beaver and Mahoning rivers to a point northwest of Warren, thence across the divide into Grand River valley, which would be converted into a large reservoir from 2½ to 4 miles wide and about 28 miles long, by the construction of a dam in the vicinity of Harpersfield, Ohio, where Grand river turns abruptly to the left into a narrow valley. A land canal from the dam to the mouth of Indian creek would connect the Grand River reservoir with Lake Erie. After a hearing before the Board of Engineers for Rivers and Harbors in March and April, 1936, the report was returned to the district engineer at Pittsburgh, Col. W. E. R. Covell, who had succeeded Major Styer, for further study.

Colonel Covell, in his report of February 24, 1937, followed in general, the location proposed by Major Styer. However, he found it necessary to move the proposed location of the land canal between Grand River reservoir and Lake Erie about three miles westward for the reason that the original location was on a glacial moraine where the construction of a canal would not be feasible. The canal, at its revised location, would have its northern terminus at the mouth of Wheeler creek on Lake Erie.

Major General J. L. Schley, chief of engineers, United States Army, reported on the project to the secretary of war for transmission to Congress on January 23, 1939. Following the recommendation of the Board of Engineers for Rivers and Harbors, he recommended "the construction of a waterway extending from the Ohio river through the Beaver, Mahoning and Grand River valleys to Lake Erie with a minimum depth of 12 ft., and generally 250 ft. wide (minimum width 200 ft.), at an estimated cost to the United States of $207,257,000 for construction, and $1,730,000 annually for maintenance and operation".

While it would appear from the above that Major General Schley gave his approval to the entire project, as a matter of fact, he did not, for he stated later in the aforesaid report:

"Since it is impossible to determine at this time the extent and effect of future possible rail rate reductions it is advisable that the completion of the waterway from

Struthers to Lake Erie in part, or in full, be undertaken only after the section to Struthers has been opened to traffic and after a further finding by the chief of engineers of economic justification, taking into consideration trends in economic conditions, rate adjustments, and changes that result from the work already finished."

It is, therefore, apparent that while the chief of engineers approves the project of a through canal from the Ohio river to Lake Erie, he does not recommend its construction until a most grave and expensive experiment has been conducted, at the expense of the taxpayers of this country. This experimental or so called "dead-end" canal would be 35 miles in length, of which 31 miles would be in the Commonwealth of Pennsylvania, and 4 miles in the State of Ohio.

The chief of engineers estimates the cost of its construction at $42,400,000 of which amount $38,500,000 is chargeable to the federal government and $3,900,000 to local interests. A committee, composed of the chief engineers of the railroads that will be adversely affected by its construction, estimates the cost of its construction at $55,462,000 of which amount $45,893,000 is chargeable to the federal government, and $9,569,000 to local interests.

Purpose of the Proposed Canal

The proposed canal would afford a means for transportation by barge between the Ohio river and Lake Erie. The chief commodities for shipment would be iron ore and bituminous coal, the ore moving southward and the coal moving toward Lake Erie. There would also be shipped over the canal some limestone and manufactured products, but such shipments would be comparatively small. The reason given by the proponents of the canal as a justification for the project is not because of insufficient transportation facilities, but in order that transportation costs may be reduced. The present facilities of the railroads, including those of the Pennsylvania, Baltimore and Ohio, Chesapeake and Ohio, New York Central, Bessemer and Lake Erie, Wheeling and Lake Erie, the Erie, and the Pittsburgh and Lake Erie are such that these railroads are now able to handle efficiently all present transportation requirements between the Ohio river and Lake Erie or any increase that may be expected for many years to come.

Description of the Proposed Canal

In accordance with the recommendations of Congress, the United States Army engineers have made surveys and studies of four proposed routes for a waterway connecting Lake Erie with the Ohio river, namely,

1. Pittsburgh-Ashtabula route via the Beaver, Mahoning and Grand rivers;
2. Allegheny-French creek route via the Allegheny river, French creek, Conneaut lake, and Conneaut and Raccoon creeks;
3. Portsmouth-Sandusky route via the Scioto and Sandusky rivers;
4. Cincinnati-Toledo route via the Miami, St. Marys, Auglaize and Maumee rivers.

The so-called Pittsburgh-Ashtabula route, which the United States Army engineers have selected as the most economic of all four of the routes under consideration, has its southern terminus at Beaver, Pa., at the mouth of the Beaver river, 25 miles below Pittsburgh.

The route, as indicated on Fig. 1, follows the Beaver and Mahoning rivers to a point about 1½ miles above Warren, Ohio, where it leaves the Mahoning river and extends in a northwesterly direction across a low point in the Ohio river-Lake Erie divide into the Grand River valley, where a summit reservoir would be created by the con-

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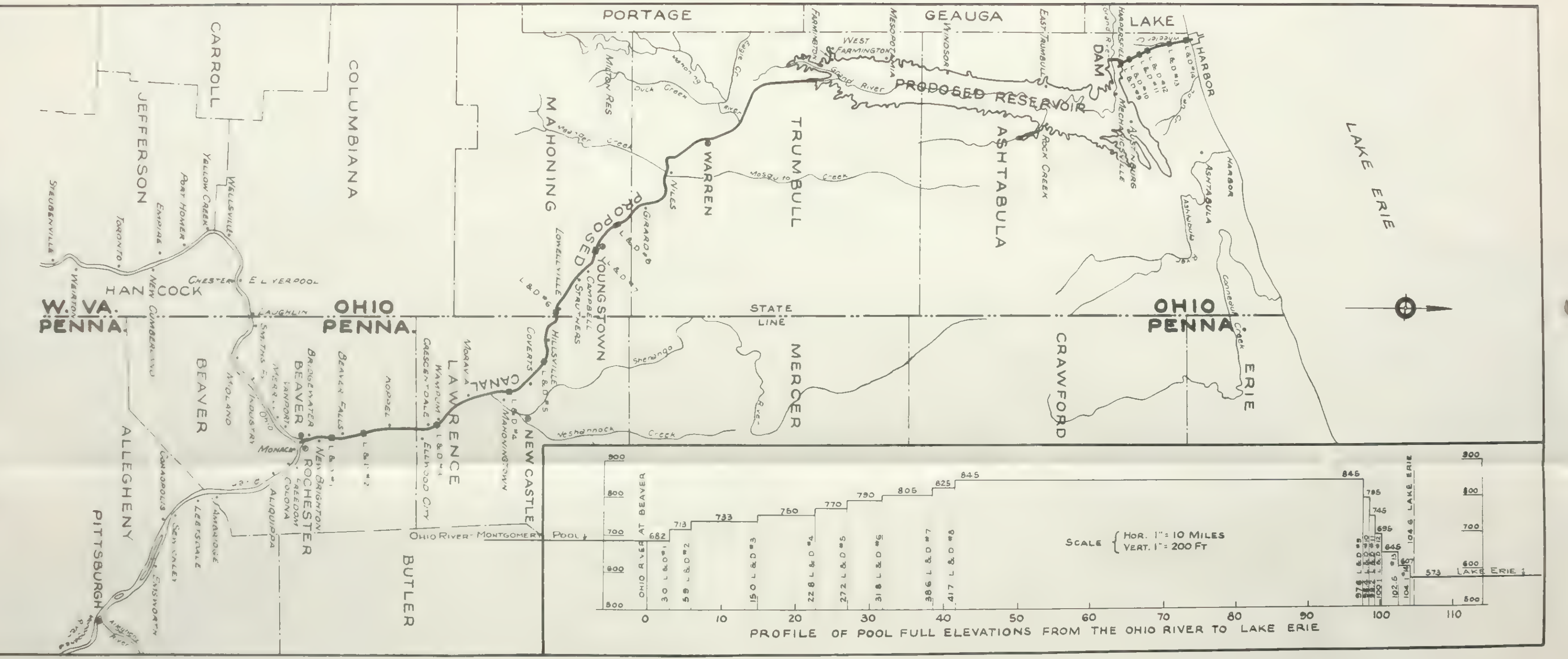
(a) Furnish free of cost to the United States title to all lands required for rights-of-way in and south of the City of Warren.



PROPOSED LAKE ERIE AND OHIO RIVER CANAL
PITTSBURGH ASHTABULA ROUTE
AUGUST 15, 1939 SCALE 0 1 2 3 4 5 MILES EXHIBIT "A"

Fig. 1

struction of a dam 115 ft. high near Harpersfield, Ohio, about 5 miles below the point at which the Grand river turns abruptly to the west, and parallels Lake Erie for a distance of approximately 25 miles to Painesville, Ohio, where it turns north to join Lake Erie at Fairport harbor. The reservoir would be 27 miles long and from 2½ to 4 miles wide. From Harpersfield, the route descends the slope to Lake Erie at the mouth of Wheeler creek, a distance of 7½ miles, where a new harbor would be constructed. The total length of the proposed canal is 104.6 miles. Plans provide for a total of 14 locks with a combined lift of 435 ft.

Montgomery dam, in the Ohio river below the mouth of the Beaver river, has a controlled pool, under low-water conditions, at elevation 682. Three dams would be constructed on the Beaver river which would result in a pool elevation of 750 at its head at the junction of the Mahoning and Shenango rivers. The Mahoning river would be canalized by means of five dams to reach the summit pool above Youngstown, Ohio, at elevation 845, which also would be the elevation of the crest of the proposed Grand River Reservoir dam at Harpersfield, Ohio. There would be six locks and dams on the land canal between Grand River reservoir and Lake Erie, the mean elevation of the latter being 573, or 109 ft. below the Montgomery Dam pool on the Ohio river.

The canal channel would have a minimum depth of 12 ft., including overcut, and a minimum channel bottom width of 250 ft., except for a distance of about eight miles through the City of Youngstown, Ohio, where a modified standard of 200 ft. minimum bottom width was adopted for the reason that the cost of construction of standard width would be prohibitive. The side slopes of channels excavated in earth would be 1 vertical to 2 horizontal, and the side slopes of rock cuts, 1 horizontal to 10 vertical. In the Youngstown district, due to the limited space available, it would be necessary to construct retaining walls instead of standard channel side slopes. Excavation of river bends would be required to such width as may be necessitated by the degree of curvature. A minimum radius of 1,500 ft. has been adopted as the standard of curvature.

The plans for the project provide for a minimum vertical clearance of 27 ft. and a minimum horizontal clearance of 250 ft., except on the restricted reach through Youngstown industrial district where the minimum horizontal clearance would be 200 ft., conforming to the proposed minimum bottom width of the canal through that territory. The excavation involved would total approximately 101,900,000 cu. yd., of which approximately 27,700,000 cu. yd., would be rock.

There would be provided at each of the 14 canal dams, double lock chambers, each 56 ft. wide by 720 ft. long. The canal facilities are designed to accommodate traffic in tows of six barges, each 26 ft. wide, 175 ft. long, and having a capacity of 1,000 tons at 8¾-ft. draft, a unit that is in more general use at the present time than any other on the Ohio and Monongahela rivers.

There would be 80 bridge crossings over the proposed waterway, of which 36 would be railway, 42 highway, one electric power cable, and one overhead pipe line. It is proposed also to construct five causeways across the Grand River reservoir.

Estimated Cost

While the recommendation of Major General J. L. Schley, chief of engineers, in his report to the secretary of war provides for the major portion of the project being constructed by and at the expense of the United States government, he recommends that, before any construction work on any part of the improvement is undertaken, local interests shall—

(a) Furnish free of cost to the United States title to all lands required for rights-of-way in and south of the City of Warren.

(b) Agree to furnish free of cost to the United States suitable spoil-disposal areas for initial work, and for subsequent maintenance as required for the section in and south of Warren.

(c) Agree to hold and save the United States free from claims for damages in connection with existing water rights for power development and other purposes, and for other damages that may occur due to construction of the waterway.

(d) Agree to operate Milton reservoir, now owned by the City of Youngstown, under the supervision of the chief of engineers, United States Army, for the primary purpose of increasing the low flow in the interest of navigation.

(e) Agree to make, at their own expense, alterations as required of existing highway and steel company bridges spanning the Beaver and Mahoning rivers and necessary road changes in connection therewith.

(f) Agree to maintain, at their own expense, all new public roadways; to maintain and operate, at their own expense, all rebuilt and new highway and steel company bridges, and to assume the cost of maintenance and operation of all new railroad company bridges constructed incident to the improvement.

(g) Agree to make, at their own expense, alterations as required in all sewer, water supply, and drainage facilities.

(h) Agree to provide, at their own expense, and as required, suitable and adequate lake and canal terminals and dredged harbor areas adjacent thereto shoreward of channel or harbor lines, in accordance with plans approved by the chief of engineers and the secretary of war.

All other expense in connection with the proposed canal, including reservoir land and clearing, rights-of-way north of Warren, Harpersfield dam, dikes, causeways, channel excavation, bank protection, walls, barrier dams, navigation dams, locks, new highway bridges and highway relocations north of Warren, the harbor on Lake Erie and all new railroad bridges and relocations, it is recommended shall be borne by the federal government.

The Board of Engineers for Rivers and Harbors, has estimated the cost of the entire project, using the division of expense above indicated, as follows:

Federal construction cost	$207,257,000	
Interest during construction	18,653,000	
Total federal investment		$225,910,000
Non-federal construction cost	$ 12,472,000	
Interest during construction	1,684,000	
Total non-federal investment		$ 14,156,000
Total estimated cost of project		$240,066,000

It will be shown later that these figures are incorrect, being entirely too low. However, using the estimated cost of $240,000,000, the per mile cost of the completed waterway would be $2,295,000, which is approximately 70 percent greater than the per-mile cost that the Board of Engineers for Rivers and Harbors had in mind when it stated in House Document 277, page 14, paragraph 37, with reference to the so-called "dead-end" canal extending from the Ohio river up the Beaver and Mahoning rivers to Struthers, Ohio, just east of Youngstown:

"The cost of this improvement will be very high, being over a million dollars per mile as compared with about $129,000 for the Ohio and $106,000 for the Monongahela, and even when improved, as pointed out by the division engineer, the waterway would be deficient in many of the attributes which are generally considered essential for successful modern barge navigation, and are found on the Ohio and Monongahela".

Although the cost of the proposed canal would be enormous, according to the United States engineers, an examination of their estimate shows items of cost that will be incurred have been omitted therefrom, and that certain other items included therein are inadequate to cover the work involved. Some of these omissions and under estimates are pointed out below.

The United States engineers estimate is based on "prices of labor and material prevailing during July, 1935". However, since that date the prices for labor and material have increased so that by December, 1938, according to the Engineering News-Record construction cost index, such prices had advanced 19 percent. Applying this 19 percent increase to the total cost as estimated by the Board of Engineers for Rivers and Harbors produces the following:

Federal Investment	$268,833,000
Non-Federal Investment	16,846,000
	$285,679,000

The United States district engineer's report (page 266, paragraph 77), estimates that an additional water supply could be obtained from Pymatuning creek at an estimated cost of $8,500,000, but nothing was included for this in the estimate, although the necessity for this additional water supply is indicated in his report (page 68, paragraph 115) in these words:

"Although the drainage areas naturally tributary to the summit levels of the canal routes and those which could be made available by diversion thereto are considerable in extent, they would not yield natural primary flow during critical years sufficient to meet the total water demand. Storage reservoirs and feeders, where required, are contemplated to supplement the natural yield of the tributary drainage areas".

The improvement of the upper Monongahela river would be necessary to carry the additional traffic that would be created by reason of the tonnage it is claimed would be moved via the proposed canal. The United States district engineer estimates this cost at $5,907,000, but it is not included in the estimate of the Board of Engineers for Rivers and Harbors.

Nothing has been included for capital cost of floating equipment (dredges, etc.), for maintenance and repair of the canal and its structures, nor for dry docks nor other facilities for the upkeep of such equipment.

The United States district engineer's report (page 306, paragraph 55), estimates the cost of terminal facilities, i. e., property, docks, loading and unloading machinery and tug boats at Lake Erie at $12,801,000, but this is not included in the cost of the canal for the reason that it is assumed it could be financed by private interests. Nevertheless, it is a capital charge and someone must provide the money. Nothing has been included for local terminals such as would be required at Youngstown and other industrial centers.

Careful estimates have been made by a committee of chief engineers of the railroads that will be adversely affected by construction of the proposed canal. These estimates indicate that the cost of the canal is greatly underestimated by the United States engineers. Especially is this true in regard to the cost of the rearrangement of railroad bridges and tracks where the under-estimate of the United States engineers amounts to over $13,000,000.

Revising the estimate of the United States engineers so as to include the items omitted, and to take care of items under-estimated, and to bring construction costs up to December, 1938 levels, the actual investment would amount to not less than the following:

	Federal Investment	*Non-Federal Investment*	*Total Investment*
Estimate of Board of Engineers for Rivers and Harbors	$225,910,000	$14,156,000	$240,066,000
Under estimates and omissions	$33,543,000	$50,721,000	$ 84,264,000
Total	$259,453,000	$64,877,000	$324,330,000
Adjusting cost to Dec. 1938 level by adding 19 percent	49,296,000	12,327,000	61,623,000
Total	$308,749,000	$77,204,000	$385,953,000

Based on these figures, the per mile cost of the canal would amount to over $3,675,000, or almost 35 times that of the Monongahela river as given by the Board of Engineers for Rivers and Harbors, almost 10 times that of the New York State canal, and over 13 times that of the Illinois waterway. No other man-made waterway has even approached such cost per mile except the Panama canal and the Welland canal, which cost two and one-half times the original estimate.

Notwithstanding the enormous cost of the proposed waterway, there are grave doubts as to the successful operation of the Grand River reservoir, upon which the water supply of the canal will depend. Mr. V. C. Smith, a practicing consulting geologist, has testified before the Board of Engineers for Rivers and Harbors that, because of geological conditions, it is impractical to impound and maintain water in the proposed reservoir. Dr. Charles R. Fettke, professor of geology at Carnegie Institute of Technology, Pittsburgh, who investigated for the United States engineers, has expressed a contrary opinion.

It should be noted, however, that Dr. Fettke's opinion corroborated Mr. Smith in many particulars, and as a result the district engineer made substantial changes in the location of the impounding dam, and of the canal outlet to Lake Erie, including the great lock system at the northern end of the canal.

Dr. Fettke agreed with Mr. Smith that the former proposed location of this outlet was "almost directly above the old valley of the preglacial Grand river". This being true, it is not improbable that this "preglacial valley" which penetrates under the reservoir, would cause leakage as stated by Mr. Smith.

A careful study of the reports of Mr. Smith and Dr. Fettke leads to the conclusion that it cannot be stated with confidence that the existing geological conditions will not contribute to an excessive loss of water by seepage. An undertaking of such magnitude should not be started until there are more positive assurances that water can be impounded in the Grand River basin to the elevation called for in the plans of the project.

Operation of the Proposed Canal

In the operation of the proposed canal, it is assumed in the United States district engineer's report that a standard tow would consist of one towboat pushing six barges ahead and with two abreast. Tows are to be 700 ft. long, and locks are designed 56 by 720 ft. to accommodate one tow without double locking. The further assumption is made that tows will maintain an average speed of four miles per hour in lock pools, exclusive of locking time, an average speed of five miles per hour through the Summit reservoir, and that the average locking time will be 29 min.

Captain E. V. Rawn, representing the Huntington, W. Va., Chamber of Commerce and Southern West Virginia Coal Operators, and Captain William Cowan, representing the Carnegie-Illinois Steel Corporation, at a hearing before the United States engineers Board for Rivers and Harbors, at Washington, on March 30 to April 2, 1936, on the proposed Lake Erie-Ohio River canal via Pittsburgh to Ashtabula route, testified that the adopted average pool speed of four miles per hour represents the speed now attained on the Ohio River system under favorable conditions, and cannot be equaled on the proposed canal and Grand River reservoir; and that transportation of the type used on the Ohio River waterway system cannot operate efficiently and safely on an artificial waterway, such as is proposed. A summary of the opinions expressed by these experienced river men, together with opinions obtained from operating river men on the Cincinnati, Huntington and Pittsburgh territories, is approximately as follows:

The proposed canal with its tortuous alinement can be traveled only at reduced speeds by river craft. In the miles of channel which will be cut through rock, contact with the channel walls will inflict serious damage to steel barges. Each of the 80 overhead bridges proposed will create a hazard by narrowing the channels and causing cross currents. The passing of two tows, even in the straight reaches of the canal, will be difficult and, through the curves and sections affected by overhead structures, priority of entrance will determine right of way, with one tow waiting for the other.

At present on the Ohio river, steamers often follow one another all day long because of inability to pass in the channel. In the canal, passing a slow tow by a faster one will be possible only if the slow tow is fully stopped; and in practice, the speed of the slowest equipment determines the speed for all following. Even in the Ohio river tows are forced to reduce speed when passing barges moored along the banks. Tows passing each other in opposite directions at intervening distances of 400 ft. or less are in danger of capsizing unless one tow floats by or reduces engine speed to a minimum.

It is particularly necessary that this safety measure be followed when a tow of empty barges passes a tow of loaded barges, in which event the greater danger applies to the loaded tow. Along the narrow canal channel proposed, intermediate harbors and transfer facilities will force all through equipment to reduce speed if there is to be no danger of moored barges being swamped by wave action.

The operating rivermen whose opinions have been consulted on canal operation are equally emphatic in their views on navigation on proposed Grand River reservoir. They regard this reservoir as a potential source of delay and danger to any tows crossing it, and are certain that no steamboat or barge of the Upper Ohio Waterway type would be safe on this artificial lake with any possibility of a storm arising. Even in the protected Ohio River system their steamboats are forced to seek shelter when storms arise, and the long pools created by the newer dams along the river system are increasing this element of danger. They state that two foot waves are dangerous to river boats and that four foot waves break up and swamp any river craft. They point out that, with the steel hawsers now in current use to connect barges, it is impossible to cut barges apart quickly, and that the swamping of one barge frequently means the loss of the whole tow.

Damage to steamboats is also certain when rough water raises the paddle wheel to less than safe submergence. This places a heavy strain on the driving mechanism, and has been known to wreck the power plant completely. If it is kept in mind that these inland waterway tow-boats have a length of about 175 ft., and that the paddle wheels submerge to a depth of only about 3 ft., it will be appreciated that wave action, even in moderate amount, constitutes a serious hazard to the operating of such craft. It may be added that these riverboats have no gunwales to protect them from shipping water, so that wind and waves are two of the greatest hazards they can encounter.

In the proposed Grand River reservoir, lying as it would on a high plateau above Lake Erie, the possibility of sudden storms would always be present. It is evident from the topography of the surrounding country that little shelter from storms can be reached by river boats even if they have storm warnings.

The facts herein presented lead inevitably to the conclusion that navigating equipment of the type used on the Upper Ohio waterway System cannot be operated safely and effectively on the proposed Grand River reservoir. It is true that a type of equipment might easily be designed which could navigate safely and with reasonable dispatch from Lake Erie to the south end of the reservoir, but certainly there is no point to an additional transfer of cargo from special type of navigating equipment to standard type of equipment when there is grave doubt as to the efficiency of operating standard inland waterway equipment through the canal itself. It seems that the proper answer to the successful navigation of the proposed canal can only be found in a type of navigating equipment which can be used throughout the entire length of the canal.

In order to appreciate some of the difficulties in connection with the operation of the proposed canal, it should be pointed out that shipments of coal and ore, would, in general, be made in barges moved by boats owned and operated by private interests, each company transporting its own commodities. Shipments of coal on reaching the lake port would be transferred to lake vessels for shipment to various points on the Great Lakes, and likewise vessels arriving at the port from the iron ore region of Lake Superior would be transferred to river barges for shipment via the canal to the steel mills at Youngstown, Pittsburgh, Wheeling, etc. The maintenance of the canal including the locks and the operation of the locks would be the obligation of the U. S. Government and no charge would be made against the steel and coal companies operating their barge fleets through the canal, or against any other private concern that may wish to use the proposed waterway.

One of the most vital and difficult problems in connection with the proposed system is the north terminal near Ashtabula. This port must be prepared to receive and promptly unload from 20 to 25 ore boats in 24 hours. Of course, the daily average will be less than this, but due to the inability of the lake carriers to maintain uniform schedules, the port must be prepared to take care of peaks that will undoubtedly reach the figure stated above. The daily average for the open season at least will necessitate the unloading of from 12 to 15 boats, and if the lake carriers are seriously delayed, costs here will be increased instead of reduced.

The facilities will have to be able to take care of a minimum of five or six boats at one time. The facilities must be designed so that the identity of individual groups of ore be preserved. There are some 125 classifications of ore of varying values, shipped by some 30 or more individual owners and consigned and shipped to some 15 or 20 different consignees. The lake carriers vary in capacity from 6,000 to 12,000 tons, and for direct shipments it is assumed that the barges will be handled in fleets of six, with a total capacity per tow on the canal of 6,000 tons or less. This feature alone prevents successfully disposing of the cargo from individual boats to barges, and creates a most difficult problem. Assuming an adequate system that will permit maneuvering of empty barges under the transfer machines, and promptly receiving from the lake carrier its entire cargo, it means that each individual shipper on the canal will, at all times, have at the north port an adequate supply of empty barges to receive his ore shipments. He must also be prepared to store, at the north port, pending shipment to the south, any surplus of loaded barges that cannot be promptly moved south on the canal, keeping in mind that the government plan contemplates units of six barges with a total of something less than 6,000 tons capacity. The difficulty of matching barges with lake carriers of varying capacities, is at once evident. And keeping in mind the fact that individual groups of ore must maintain their identity, further seriously complicates the problem.

Another feature that is difficult to solve is synchronizing the time of arrival of the lake boat and of the canal units. It would seem that this can only be solved by providing a large number of empty barges, together with sufficient berthing space for a very large number of loaded barges. Unless the barges on the canal are pooled, it would seem entirely out of the question for each individual interest to work out his individual problem of barge supply so as to receive promptly the ore consigned to him. If this is not done promptly the situation with respect to delay to the lake carriers will produce an impossible situation.

The difficulties encountered in transferring ore at the port on Lake Erie are further complicated by the necessity of providing space at the docks for the storage of an ample supply of ore for shipment to the south after the season of open navigation on Lake Erie has been closed. It would be necessary to arrange ore piles in this space so that shipments could be made by either rail or water because a very considerable portion of stored ore would move during the winter months, requiring rail transportation, while the needs of the mills would necessitate frequent shipments of certain grades from storage by barges during the open navigation season on the canal. Storage space should be arranged for probably six to eight million tons of ore. The method of placing this ore in storage, which would have to be handled from the same machines on the dock front, presents a transfer problem without precedent. In order to maneuver the barges under the unloading machines promptly, so that each individual boat at the dock front would be promptly served, and in order to provide sufficient maneuvering space so that individual boats may be served with an adequate barge supply, which barges can be promptly shifted and replaced with empties, without interfering with the supply of an adjacent boat, calls for considerable open water behind the unloading machines, and yet if storage is to be provided, the problem of moving the ore from the unloading machine back to storage and across the area set aside for the handling of the barges, would create a problem that seems to be almost insuperable. A further difficulty with respect to storage presents itself in the necessity of maintaining the individual identity of each group of ore, as well as the question of diverse ownership. The arranging of storage piles to meet these conditions would require enormous areas and long travel distances with their attendant high costs.

All of the difficulties suggested above with respect to ore would be present in the problem of handling coal, together with additional difficulties that must be given careful consideration.

No Economic Justification for the Proposed Canal

The "syllabus" of the report dated February 24, 1937, of the United States district engineer, contains the following statement:

> The district engineer is of the opinion that such a proposed project, which is estimated to cost $178,965,000, to warrant its adoption should have some reasonable margin of economic justification. Under a favorable condition of back-haul for the prospective traffic for the waterway, the excess of average annual benefits, including flood control benefits, over average annual economic charges is estimated to be

$3,701,000, and under a less favorable basis, $2,741,000. Such margins of prospective benefits would result if the following conditions obtain:

(a) No material rise in construction costs as estimated in the current report.
(b) Development of the anticipated volume of traffic.
(c) Realization of the estimated unit transportation savings.

The Board of Engineers for Rivers and Harbors on December 20, 1938, nearly two years later, after a painstaking and detailed review of the district engineer's report, estimated the cost of construction at $240,066,000. This increase of $61,101,000 is accounted for by the provision of additional facilities, revision of the plan for the reservoir proposed in the Grand River valley, and the inclusion of interest during construction.

At the same time this board estimated that the excess of annual benefits over annual economic costs would amount to $8,000,000, a net return of 3⅓ percent on the capital to be invested. Upon this narrow margin of return, resulting from an estimate of annual benefits from two to three times as great as those estimated by the district engineer, the conclusion is reached that the construction of this waterway is "economically justified".

This, and this alone, is the basis for the board's recommendation that the canal be built. It is not claimed that any military advantage will result, nor that the canal would be of any value for the transportation of materials in time of war or other national emergency.

It is admitted that the territory to be transversed is now "well served by highly developed railroad facilities and improved highways", and that in recent years the traffic over these railroads has decreased.

It is admitted that the canal as a whole will be closed to traffic at least four months of the year, so that during these months other means of transportation must be depended on.

It is admitted that the freight rates charged by the railroads have been found by the Interstate Commerce Commission to be just and reasonable.

It is not claimed, and in a previous report it was specifically denied, that the construction of this canal would result in the development of any now undeveloped natural resources, and it is admitted that such traffic as would move in the canal would be simply diverted from existing means of transportation.

It is not claimed that the "average annual benefits" estimated in the Army engineers' report would in reality be beneficial to the people of the nation as a whole, that is, to those whose money must pay for the project. These so-called "benefits" result from the differences between the estimated savings in transportation costs and the estimated annual charges (interest, depreciation, operation and maintenance) that would result if the canal is built. The savings in transportation costs would benefit those actually using the canal—the annual charges would be paid out of the public treasury. How then could there be any "benefit" to the nation?

The theory is that the "savings" would be passed on in the shape of reduced prices to the consumer, but this theory is manifestly untenable. Any savings in costs would without doubt merely add to the profits of the producer. This was recognized in the report heretofore referred to made March 19, 1925, by Col. C. W. Kutz, then United States district engineer, when he states: "What part of these special benefits would be reflected in reduced prices to the consumers of coal, steel and iron is problematical". Senator Wheeler, of Montana, chairman of the Senate Committee on Interstate Commerce, publicly stated at a hearing on April 6, 1939, that the users of "subsidized rivers and barge lines never pass on to the consuming public the benefits of low cost water transportation" and a witness (representing waterway interests) admitted that he did not know of any price reductions.

But suppose, for the sake of argument, that the above mentioned theory is correct. Then the economic justification depends upon the accuracy of the estimates. Are the estimates of construction cost, of annual economic charges and of transportation savings, as made by the Army engineers, correct?

As previously shown, because of under-estimates of the work to be performed and of items omitted from the report of Army engineers, and because of rising costs, the actual investment would amount to approximately $386,000,000 instead of $240,066,000 as estimated by the Board of Engineers for Rivers and Harbors.

The final report submitted to Congress estimates the annual "benefits" at $8,000,000 —an amount nearly double the most optimistic estimate of the district engineer. How was this increased estimate of "benefits" obtained?

To answer this it is necessary to examine the methods used by the district engineer.

Based on his estimates of the cost of the project, he arrived at an "annual economic charge" of $10,484,000. This includes interest, depreciation, maintenance and operation of the canal and its structures. He also estimated the tonnage of coal, iron ore and lime stone that would move on the canal, based on the movements by rail to the same destinations for the average of the period 1925 to 1934, and estimated the bare cost of moving this tonnage by water, without any allowance for profit or taxes. This cost he compared with the cost of moving the same tonnage at current rail freight rates and called the difference a "transportation saving". The difference between this "transportation saving" and the "annual economic charge" he called the "annual benefit".

In estimating his water-transportation costs he proceeded upon two theories:

Theory 1. With back-haul fully credited.
Theory 2. With back-haul credited except to the Youngstown district.

He used the following basic ton-mile costs for water transportation:

On the Monongahela river	4.0 mills
On the Ohio river	3.0 mills
On the canal	5.2 mills

He estimated the total annual tonnage that would move on the canal at 22,480,000 tons, with a statement that this estimate is conservative and *may* be exceeded by 10 percent. He also stated that the transportation savings *may* be greater than estimated. He failed to take into account that the cost of construction *might* exceed that estimated, with a consequent increase in the annual economic charges.

His results may be shown as follows:

	Theory 1	*Theory 2*
Annual tonnage transported	22,480,000	22,480,000
Annual transportation savings	$13,910,000	$12,950,000
Annual flood control benefits	275,000	275,000
Total	$14,185,000	$13,225,000
Annual economic charges	10,484,000	10,484,000
Net annual "benefits"	3,701,000	2,741,000
Possible increase transportation saving	803,700	679,400
Possible annual "benefits"	$ 4,504,700	3,420,400

The results obtained by the Board of Engineers for Rivers and Harbors may be shown as follows:

Annual tonnage transported	28,000,0000
Annual transportation saving (Note A)	$20,000,000
Annual flood control benefits	275,000
Total	$20,275,000
Annual economic charges	12,157,000
Net annual "benefits"	$ 8,038,000

Note A—Based on water transport cost of 3 mills per ton-mile.

Under date of December 15, 1937, the Upper Ohio Valley Association presented to Board of Engineers for Rivers and Harbors an analysis of the District Engineer's report, containing data to show:

1. That the estimate of tonnage (22,480,000 tons) that would move on the canal was greatly in excess of a reasonable expectation, and included tonnages that could not possibly be economically routed that way.
2. That his estimates of unit (per ton) transportation savings were grossly exaggerated.
3. That even admitting that the full 22,480,000 tons used by him did move on the canal, the application of correct unit costs would reduce the annual transportation savings to:

   Under Theory 1—$4,600,000
   Under Theory 2—$4,310,000

4. That the "annual economic charges" would amount to $12,027,000, not including any losses of tax revenues resulting from the construction of the canal and the reduction in railroad revenues. These tax losses were estimated at $2,067,000 producing a total "economic charge" of $14,094,000, which set against the maximum transportation saving of $4,600,000 would produce a net loss to the public of $9,494,000.
5. That his transportation savings were predicated on an incorrect basis, in that he compared the bare cost of movement on the canal, without any allowance for profit to the barge-line operators, or for taxes, with the charges resulting from the application of rail freight rates.
6. That any transportation savings would accrue to a comparatively few industries and localities, to the disadvantage of other industries and localities not able, by their situation, to make use of the canal.
7. That the effect on the railroads of this diversion of traffic would be harmful in the extreme. The loss of the 22,480,000 tons diverted would entail a loss of gross revenue amounting to $20,096,500 per year, and would force from 8,000 to 10,000 railway employees out of employment.
8. That coal mine operators and miners would suffer by reason of the curtailment of railroad purchases of fuel, and by dislocation of employment resulting from the closing of mines or the transfer of operations from inland to river mines.

Notwithstanding these criticisms, the Board of Engineers for Rivers and Harbors, under date of December 20, 1938, reported in favor of the canal. This report, by using a tonnage nearly 25 percent greater than that of the district engineer, and by using a cost of 3 mills per ton mile for transportation on the canal produced an estimated annual transportation saving of $20,000,000.

It ignored the fact that construction costs had risen 19 percent and that a relative increase in "annual economic charges" would result.

It ignored the effect on the railroads and on labor, and based the "economic justification" solely on a comparison of the estimated "transportation savings" and "economic charges".

It failed to consider that if the tonnage predicted should fail to develop, the "transportation saving" would also fail to materialize, but that the "economic charges" would be fixed, and might be greatly in excess of their estimate.

Analysis of the aforesaid report has been made but it is not at present available for publication. It may be said, however, that disregarding all collateral effects, this analysis shows conclusively that even from a strictly financial view point the proposed canal has no economic justification, and its construction, at the expense of the taxpayers of the United States, is not warranted.

Conclusions

1—The Ohio River navigation system consists of 3,612 route miles (981 on the Ohio river between Pittsburgh and Cairo, and 2,631 on tributary streams), and represents an investment on the part of the taxpayers of the United States of some $234,000,000, and a total expenditure (as of January 30, 1938) including maintenance and a relatively small amount of unexpended appropriations, of $362,000,000. Based on the operation during 1937, a total of about 4,205,000,000 ton-miles of freight was transported on these rivers, a large percentage of which would have moved on the railroads had government improved waterways not been available.

The annual cost of transportation on these rivers to the nation is estimated at approximately $34,000,000, of which about one-half is paid or absorbed by the taxpayers and the other half by the users of the waterways.

There is no evidence of record that the users of the waterways pass on to the public in general the savings that accrue to them as compared with the rail freight rate. Waterway transportation may be cheap to the favored shipper but is costly to the taxpayers, who foot the bill for improving, operating and maintaining the locks, dams and channels.

2—Although the freight traffic density of the New York State barge canal has increased from around 362 million ton-miles in 1922 to over one billion ton-miles in 1937, the operating results for the latter year show the total cost of transportation 40 percent in excess of the cost of the average rail rates in the United States. The total cost of transportation on the canal was 13.23 mills per ton-mile, of which 34 percent was paid by the users and the balance by the taxpayers of the state. It is obvious, therefore, that the construction and maintenance of the canal has not been justified up to the present time, and it is quite doubtful if it ever will be.

3—Analysis of all information pertaining to the proposed Lake Erie-Ohio River canal available to the committee shows beyond all doubt that from strictly a financial viewpoint, the proposed canal cannot be economically justified, and its construction at the expense of the taxpayers of the United States is not warranted.

This report is offered as information, and it is recommended that the subject be continued.

Appendix F

(7) Effect of High Speed on Railway Operating Expenses

M. F. Mannion (chairman, subcommittee), E. G. Allen, B. T. Anderson, C. W. Breed, Olive W. Dennis, J. F. Pringle, H. F. Schryver, B. J. Schwendt, H. A. Shinkle, L. K. Sillcox, H. M. Tremaine.

Last year the committee outlined the six general accounts which go to make up Railway Operating Expenses, and stated that only three, namely maintenance of way, maintenance of equipment, and transportation expenses were affected by speed. Attention was called to the lack of available data from which a definite determination of effect of high speed could be obtained.

Maintenance of Way Expenses

In its attempt to study maintenance cost under former speeds and present high speeds, the committee finds that, concurrent with the sharp increase in both passenger and freight train speeds, there has been a betterment in track structure and alinement, principally by the use of heavier rail and curve reduction.

As pointed out in last year's report of Committee 22—Economics of Railway Labor, the use of heavy rail reduces the amount of labor necessary to maintain a set standard of track maintenance. This report also pointed out the fact that the life of rail, ties and other track materials was increased by the use of the heavier rail. This increase in the life of material, together with the sizeable reduction in track labor, reduced maintenance costs far more than any increase in maintenance costs brought about by high speed. As a result, the present-day maintenance cost on many high-speed territories is lower than it was under former speeds.

The continuously increasing investment in track and other property, together with improved maintenance methods, resulting in decreased maintenance costs, makes it impossible to determine from any cost data the effect of high speeds on such costs.

Maintenance of Equipment Expenses

New and radically different designs of equipment are being used in high-speed service. The maintenance cost per mile or ton-mile of this equipment cannot be definitely determined due to the short period it has been in service. Annual equipment maintenance cost for the first few years of service are not true costs, as it is a known fact that such expenses increase as the equipment becomes older.

Transportation Expenses

A study of the effect of operation of 12 fast passenger trains, on freight train movement on both single and double-track territory was made by one of the mid-western roads. The test was based on ten days' operation during two different months, with the following results:—

No. of Freight Trains Delayed	*Time Delayed*	*Overtime*	*Average Delay per Train*
138	60 hr. 4 min.	1 hr. 55 min.	26 min.

The average delay per train was practically the same for double and single-track territory.

This road furnished the following comments in connection with the study.

> You will note that there was practically no overtime by reason of these delays, and no necessity for reduction in tonnage.

> The terminal delay to freight train when it occurred is also included in the above statement, but it was practically nil and naturally should be.
>
> If the object of this survey is to show to what extent these fast trains, as fast trains, have upon the operation of freight trains as compared with the effect which the more conventional schedules of passenger trains would have on freight trains, the above will not answer, but can be arrived at by reducing the figures 40 percent. In other words, if these present fast trains were to be operated, but on a slower schedule, the average delay would be 16 min. each instead of 26 min. It is true that the operation of these fast trains, or any additional passenger trains, does have an effect on the freight train movement, but with the exception of the single-track territory where they operate it makes very little difference in the overhead time maintained by the freight trains. In double-track territory, day in and day out, freight train schedules are satisfactorily maintained, and without any reduction in tonnage.
>
> If these fast trains were to be eliminated, I would estimate our savings in the expense of other train operations to be not more than $2,500 per year, or, if they were to be placed on slower schedules, these savings would not exceed $800 per year.

The following reply was received from an eastern road operating a new light-weight train over territory, part of which was double and part single track.

> We wish to point out to you that our train is not operated at speeds in excess of those permitted steam trains, that it operates on schedules so set up that it does not overtake and pass any other passenger train. We have no special clearance rules applying to its operation, and can find no delays to other trains either freight or passenger which are abnormal because of the presence on the road of this train.

The committee is continuing its study of the train sheet of another road which has high speed passenger operation.

This progress report is offered as information.

Appendix G

(8) Effect of Rail Lubrication on Train Operation

J. A. Parant (chairman, subcommittee), Richard Brooke, R. P. Forsberg, C. H. R. Howe, E. A. Humphreys, F. H. McGuigan, Jr., L. G. Morphy, H. R. Peterson, L. S. Rose, H. M. Tremaine, R. E. Van Atta.

Foreword

The application of oil or grease either by hand or with mechanical devices to the gage side of the high rail of curves or to the wheel flanges, has been practiced by both steam and electric railroads for a number of years. The purpose of the lubrication has been to reduce the abrasion on the head of the rail as well as on the wheel flanges. On electric car lines the sharp curves in subways and at street corners are often lubricated to reduce the screeching noise.

The Committee on Track has contributed valuable reports to this Association on the subject of lubrication, and reference to these reports was made in last year's preliminary report of this committee. Briefly, the Track committee's reports covered the methods and effect of lubrication, types of lubricators, costs, etc.

It is logical to expect that any reduction in the abrasive action on the rail and the wheel flanges while equipment passes through curves, will be reflected in reduced train resistance in the same territory. Hence the assignment "Effect of rail lubrication on train operation."

After being informed early in 1939 that the Denver & Salt Lake Railway was planning to install 14 mechanical lubricators between Utah Junction, Colo., and the east portal of the Moffat tunnel, the committee made arrangements for dynamometer-car tests over this territory before and after the rail was lubricated. Through these tests your committee has endeavored to measure and determine the reduction in train resistance on curves realized as a result of lubrication, and its effect on train operation.

Description of the Territory

In the 45.63 miles of track between Utah Junction and the east portal of the Moffat tunnel there are 112,809 ft. of track with an average curvature of 6.1375 deg. For the greater part of the distance the grade is two percent, compensated for curvature at the rate of 0.035 percent per degree of curvature. There is a difference in elevation between MP 5 and the Moffat tunnel of approximately 3,775 ft.

Make Up of the Train

A train, representative of one generally handled over this run, was made up and held intact for all the tests. This train consisted of the dynamometer car, 4 loads of coal, 25 gondola cars and the caboose. D. & S.L. Locomotive 203 was used in all tests and the auxiliary water car was considered as a part of the locomotive and placed ahead of the dynamometer car. The total weight of the cars and caboose was 898.6 tons, and that of the locomotive and water car was 377 tons. Although this is not a tonnage train, the committee was advised that it represented all that can safely be handled between Utah Junction and Phippsburg, a distance of 168 miles, inside the 16-hour limit.

Tests

The first three test runs were made after the lubricators were installed, but before any grease had been applied to the rail. The 14 lubricators were then charged with grease and after being operated for 13 days, during which time approximately 200 trains passed through them, the last three test runs were made with the rail and flanges lubricated. A continuous dynamometer record was made of the drawbar pull (train resistance) and the speed for each of the six test runs, and from the records tabulations were made at about 150 mile-post locations on each run.

Computations

The resistance of a train on level tangent track, often called rolling resistance, varies with the speed. If, therefore, the speed on two runs is not identical, direct comparisons cannot be made with the drawbar-pull data. However, this level tangent track resistance is a variable that can be eliminated by comparing virtual grades. The virtual grade resistance includes actual grade resistance, resistance to acceleration or deceleration—momentum grade, curve resistance, and wind resistance. It is representative of the difference between the drawbar-pull or total resistance and the train resistance on level tangent track at whatever speed the train is making. The resistance on level tangent track has been determined by elaborate tests published by the University of Illinois.

The resistance of the test train was obtained by determining the total resistance of each car in the train and then, from the total resistance of the train, finding the average level tangent track resistance per ton.

Determination of Curve Resistance

There were 13 curves on the test runs that are as long as, or longer than, the test train. Five of these curves are located at points where slow orders, stops or meeting points precluded an accurate determination of curve resistance. Five more curves are located at points where changes in grade or reverse curves resulted in such changes in speed that an accurate determination of the momentum grade could not be made. (With the light tonnage of this test train and the severe grades of the line, acceleration and deceleration naturally occur in very short distances). There remain, therefore, three curves on which the determination of curve resistance could be made.

The curve resistance on these three curves for the three test runs before lubrication averaged the equivalent of a 0.0276 percent grade per degree of curve, and the maximum for any one test was a 0.0395 percent grade per degree of curve. After lubricating, the average curve resistance on the same curves averaged a 0.0137 percent grade per degree of curve, and the maximum for any one test was a 0.0211 percent grade per degree of curve. It can, therefore, be stated that the tests indicate that rail and flange lubricators properly located and properly functioning will reduce curve resistance approximately 50 percent.

This reduction in curve resistance may be applied to any railroad. However, in the section of track from Utah Junction to the east portal of the Moffat tunnel the elevation lost by curve resistance before and after lubrication is as follows:

	100 ft. of Curvature	*Average Degree of Curves*	*Curve Resistance per Degree*	*Ft. of Elevation Lost*
Before lubrication	1,128.09	6.1375	0.0276	191
After lubrication	1,128.09	6.1375	0.0137	95
Reduction				96

It will be noted that the lubricators save the equivalent of 96 ft. of elevation in the 45.63 miles, or reduce the operating virtual grade 0.04 percent. An effort was made in all six tests to keep the speed the same as nearly as possible. If, however, the speed is allowed to increase as the resistance decreases, there will be a further reduction in the virtual grade due to the momentum effect of this additional speed.

Although few new railroads have been located or built in the past few years, consideration should be given to the effect of rail lubricators in reducing curve resistance when developing new location and grade-revision studies in the future.

Operating Virtual Grades

The operating virtual grades have been determined at the previously mentioned 150 mile-post locations for each test. This information was plotted on what may be termed virtual-grade charts, separating the tests made before from those made after lubrication. The averages of each of these series of tests were then plotted.

The average speed was practically identical for both series of tests. Without lubrication the average virtual grade was 1.59 percent and after lubrication it was 1.548 percent. The reduction in operating virtual grade is therefore 0.042 percent which, by the way, checks very closely with that computed from the curve resistance values, especially since the virtual grade charts take into account the effect of taking sidings at three different locations on the average runs. If the speed were allowed to increase as curve resistance is decreased by lubrication, it is safe to state that the additional momentum would reduce the virtual grade by 0.008 percent, thereby making the total reduction 0.05 percent.

Tonnage Ratings

Tonnage ratings were set up on the car-factor basis. The total resistance and average resistance per ton for different consists were computed and the pounds of resistance per ton were determined for the average tons per car. The locomotive was rated at 95 percent of its capacity.

On this part of the D. & S.L., where the operating virtual grade is high, the reduction in curve resistance makes a less favorable showing than would be the case on a railroad with a lower grade. However, it is on the heavy-grade railroads that the greatest curvature is generally experienced.

The empty-car movement on this railroad is predominantly in the direction of the test and it was found that through lubrication the tonnage can be increased by 2.6 percent. However, if this same amount of curvature existed on a railroad operating at a virtual grade of 0.8 percent, the train resistance would be reduced 4.4 percent for trains of light cars and 5.1 percent for trains of heavy cars.

Conclusions

Rail and flange lubricators, properly located and functioning will effect a reduction in train resistance and result in an increase in tonnage ratings where grade on curves controls the train load.

Acknowledgments

These tests were made possible through the co-operation of the Denver & Salt Lake Railway, which provided the locomotive, track, cars, train crew and other facilities, and the Chicago, Burlington & Quincy Railroad, which tendered the use of its dynamometer car and the services of the dynamometer-car engineer. For the important assistance and co-operation of W. C. Jones, chief engineer, Denver & Salt Lake; P. H. Smith, dynamometer engineer of the Burlington; A. E. Perlman, engineer maintenance of way, Denver & Rio Grande Western, and to the operating and mechanical officers of the D. & S.L., the committee expresses its appreciation.

The report is presented as information.

Appendix H

(9) Economics of Railway Location and Operation as Affected by Railway Electrification

E. E. King (chairman, subcommittee), B. T. Anderson, V. T. Boughton, L. E. Dale, E. K. Eugene, F. N. Nye, C. B. Stanton, H. M. Stout, W. D. Wiggins, and H. W. Williams.

Last year the subcommittee reported on the electrification of steam lines in Canada and in the United States. This year the subcommittee prepared a preliminary report in the form of a table on the electrification of steam lines in all countries of the Western Hemisphere, and in Africa, Australia, New Zealand, and India. Warring and near-warring nations of Europe and the Orient were not included. This preliminary report was made up partly from information taken from the Report, "Electrification of Steam Railways", prepared by the Railway Electrification committee of the National Electric Light Association and published in March, 1933, by the Liquidating committee of that association, as Publication No. 247; partly from data taken from the periodical, Railway Gazette, London; and partly from materials supplied by the Railway section, Transportation division, Bureau of Foreign and Domestic Commerce, Department of Commerce, Washington, D.C. The headings in the table were practically the same as in last year's report.

To bring the preliminary report up to date as far as possible, prints of the table were sent to the Railway section of the Department of Commerce, mentioned above, to be forwarded to its representatives abroad. These representatives were asked to communicate with the staffs of the railroads under consideration in the attempt to correct the data on the prints in accordance with current conditions. The Railway section had previously agreed to undertake this service for the subcommittee.

Due to lack of time, the prints have not been returned and no materials are therefore available for this year's report. The recent declarations of war may be the occasion for some delay.

This report is submitted as information with the recommendation that the subject be continued.

Appendix I

(10) Compile Operating Data Essential to Establish Units for Making Line and Grade Revisions to Meet Operating Requirements

J. M. Farrin (chairman, subcommittee), J. C. Bradley, S. B. Clement, H. H. Edgerton, J. L. Haugh, Fred Lavis, R. S. Marshall, F. H. McGuigan, Jr., F. N. Nye, John S. Worley.

The fundamental requirement to justify either line or grade revisions is that when completed the resulting operation will show a profit sufficient to pay a return on the total net cost of the improvement. Generally speaking, this return should total 15 percent, of which 5 percent is to cover interest charges and 10 percent is to take care of uncertainties and fluctuations of traffic. In lieu of a profit there may be special cases in which safety or competition will force an improvement irrespective of its cost, but for whatever reason a revision is made estimates of the total cost of conducting traffic before and after changes should be made for the information of all concerned.

There are three ways in which operation can be bettered, namely:

(a) Line and grade revision.
(b) Substitution of heavier and more modern power.
(c) More intensive supervision.

Generally speaking, line and grade revisions affect both the tonnage of trains and coal consumed, while the substitution of heavier power usually affects only the tonnage of trains. Operating data to compare the costs of (a) and (b) are similar, and as (c), more intensive supervision, does not involve such data, it will not be discussed further.

Development of Present Costs

In order to develop present costs it is desirable to use figures obtained from the operating district involved and to apply such costs to the following traffic data covering a period of at least one year in which traffic is normal:

1. Gross ton-miles of freight traffic, including locomotives, in each direction.
2. Gross ton-miles of passenger traffic, including locomotives, in each direction.
3. Number of each class of freight trains in each direction, divided to show:
    (a) Number of fast freight trains each way.
    (b) Number of slow freight trains each way.
    (c) Number of local freight trains each way.
4. Number of passenger trains each way.
5. Number of freight-train miles.
6. Number of passenger-train miles.
7. Number of freight-train hours.
8. Number of freight locomotives of each type and size.
9. Number of passenger locomotives of each type and size.
10. Number of locomotive miles.
11. Number of helper locomotive miles.
12. Number of gross tons per train-hour in freight service.
13. Cost of coal consumed in freight service.
14. Cost of coal consumed in passenger service.

15. Cost of water consumed in freight service.
16. Cost of water consumed in passenger service. (Water for (15) and (16) to be figured on the basis of 7 pounds of water per pound of coal)
17. Cost of oil and other supplies, freight service.
18. Cost of oil and other supplies, passenger service.
19. Cost of locomotive repairs per locomotive mile.
20. Wages of enginemen, freight service, per train hour.
21. Wages of trainmen, freight service, per train hour.
22. Wages of enginemen, passenger service, per train hour.
23. Wages of trainmen, passenger service, per train hour.
24. Maintenance of way and structures expense for the district.
25. Car repair expense per car mile.

With the selected items of expense, the approximate cost of the present operation can be figured and arranged in tabular form, after which the same information should be estimated for the proposed improvement, using cost data and actual experience of the railroad over the district. Attention is called here to the fact that in case the proposed improvement is such that longer trains can be hauled or larger and heavier motive power substituted, it will be necessary to consider the length and location of sidings, the strengthening of bridges, signal changes, enginehouse enlargements and other special work, and add the cost of the changes required to get a total cost of the improvement upon which to determine whether or not it is justified. Also, heavier trains generally mean more road time which may increase overtime.

With the information on present costs, a comparison with the expense of operation after the improvements have been completed is arrived at as shown in Statement A.

Expense items making up Statement A should be actual for present operation and estimated for the proposed operation, the estimate being based on the railroad's own experience over the district being considered. Items for which the railroad has had no experience, or regarding which reliable data are not available, should be estimated on the basis given below under each item:

1. Total Cost of Improvement

This item will be zero under the present operation and must be estimated for the proposed operation giving due credit for salvage.

2. Interest

This item is generally taken at five percent of the total net out-of-pocket cost of the improvement, and should include the cost of new power purchased to make the improvement effective, but should not include the transfer of power from other districts. There will be no charge for this item under present operation.

3. Replacement

This item will be zero under the present operation. Under the proposed operation charge as follows:

Rail and Fastenings.—Charge only for that portion in excess of that used in the present operation on the basis of experience. In the absence of actual experience or reliable data charge as follows:

Cost in place, less salvage value

90-lb. rail life 215,000,000 tons
100-lb. rail life 255,000,000 tons
112-lb. rail life 320,000,000 tons
131-lb. rail life 400,000,000 tons

For life on curves use the following percentages of above tonnage life

Degree of Curve	*Without Oilers, Percent*	*With Oilers*
0	100	Subject to special investigation
1	87	
2	73	
3	60	
4	48	
5	38	
6	30	
7	22	
8	16	
9	12	
10	10	

Bridging Steel.—In absence of own experience use life of 50 years.

Creosote Trestles.—In absence of own experience use life of 25 years.

Enginehouse Additions: In absence of own experience use life of 50 years for frame and 100 years for brick or concrete.

Other Buildings.—Life of 50 years for frame and 100 years for brick and concrete.

Signals.—Life of 30 years.

4. Transportation Costs

Items under this head represent a charge to both present and proposed operations but in different amounts. Total payroll for items (a), (b), (c), and (d) are governed by agreements with the men pertaining to each particular railroad and to districts on the same railroad and vary with mileage time and class of engine. The costs of these items having been developed for present operation their costs for the proposed operation should be estimated.

Engine Terminal Expense: For present and proposed operations this is the cost of handling power at terminals, which may not be the same, and if there is a difference, charges for each must be determined and added. These charges should be arrived at on a total charge basis rather than a charge per engine as this account takes in so much supervision and general expense that a variation of a few engines may not affect its total appreciably.

Fuel: This item is sometimes hard to allocate, especially for short districts, but as it is generally an important item of expense, its present cost must be determined fairly accurately. If the proposed improvement does not involve changes affecting grade, the unit cost of present operation per 1,000 gross ton-miles can be used. If the grade is affected the pounds of coal can be determined for differences in grades on the basis of 3.3 lb. of coal per 1,000 tons per foot raised. Similarly coal saved in curve reduction can be estimated by converting curve resistance to equivalent grade resistance on the basis of a 0.04 percent grade as the equivalent to one degree of curvature.

Water: Water consumed is in direct ratio to the coal used, on the basis that one pound of coal evaporates seven pounds of water. In the absence of actual water costs charge water at the rate of 10 cents per 1,000 gal. to both operations.

Lubricants: This item is small and it is sufficiently accurate to charge both present and proposed operations per locomotive mile on the basis of present costs.

Other Supplies: This item is small. Charge both present and proposed operations per locomotive mile on the basis of present costs.

5. Maintenance of Equipment

Freight and Passenger Locomotives: This item varies greatly with the classes of locomotives and their speeds. However, it is sufficiently accurate to use the system cost per locomotive mile for each class of locomotive and multiply this figure by miles run by each class of locomotive over the district being considered and make proper charges to both present and proposed operations.

Car Repairs.—Charge to both present and proposed operations on the mileage basis, based on the system.

6. Maintenance of Way and Structures

Way.—This item varies with the location, amount and character of traffic and standard of maintenance, which makes it necessary to develop actual costs for each location and then to apply these costs on a mileage basis to both the present and proposed operations, giving consideration to new roadbed and drainage. Improvements involving a change in the size of rail will affect maintenance as follows:

Assume 131-lb. rail equals 1.00, then
112-lb. rail will cost 1.18 times
100-lb. rail will cost 1.37 times
90-lb. rail will cost 1.54 times

Structures.—Steel Bridges: This item will be zero for the present operation and 75 cents per additional lineal foot per year for lengths up to 200 ft. For greater lengths make special investigations.

Creosoted Wood Bridges.—This item will be zero for the present operation and average 30 cents per foot for the proposed operation.

Buildings.—This item will be zero for the present operation and two percent per year for the increase in the size or number of buildings for the proposed operation.

Signals.—This item will be zero for the present operation and $150 per year per mile for single track and $200 per year per mile for double track, and subject to special investigation for the proposed improvement.

7. Taxes

Where these are a factor they should be considered.

It is recommended that this report be accepted for publication in the Manual, and the subject discontinued.

STATEMENT A

ANNUAL COST OF PRESENT OPERATIONS COMPARED WITH ESTIMATED COST AFTER IMPROVEMENTS ARE MADE

Item	*Present*	*Proposed*
1. Total net cost of improvements complete including changes in sidings, terminals, signals, additional power, etc.	......	......
Annual Cost		
2. Interest on net cost, 5 percent	......	......
3. Replacement		
(a) Rail and fastenings including sidings	......	......
(b) Bridging; steel	......	......
Wood	......	......
(c) Enginehouse additions	......	......
(d) Other buildings	......	......
(e) Signals	......	......

Item	*Present*	*Proposed*
4. Transportation Costs		
(a) Wages, freight enginemen	......	......
(b) Wages, passenger enginemen	......	......
(c) Wages, freight trainmen	......	......
(d) Wages, passenger trainmen	......	......
(e) Enginehouse expense	......	......
Freight	......	......
Passenger	......	......
(f) Fuel, freight	......	......
Passenger	......	......
(g) Water, freight	......	......
Passenger	......	......
(h) Lubricants, freight	......	......
Passenger	......	......
(i) Other supplies, freight	......	......
Passenger	......	......
5. Maintenance of Equipment		
(a) Freight locomotives	......	......
(b) Passenger locomotives	......	......
(c) Car repairs	......	......
6. Maintenance of Way and Structures		
(a) Way	......	......
(b) Bridges; steel	......	......
Wood	......	......
(c) Buildings	......	......
(d) Signals	......	......
7. Taxes	......	......
Total Annual Cost	......	......

Appendix J

(11) Effects of Speeds in Excess of 75 Miles Per Hour on the Economics of Railway Location

C. W. Breed (chairman, subcommittee), E. G. Allen, J. A. Anderson, S. E. Armstrong, J. C. Bradley, J. H. Dyer, E. E. Kimball, F. A. Russell, O. E. Selby, J. E. Teal.

The proceedings of this Association contain two reports on this subject, one in Vol. 37, pages 109–11, which treats briefly of maximum and average speeds, items affecting speed, and economic justification of high speeds; the other in Vol. 39, pages 485–496, which contains records of train speeds, including the log of a non-stop run of 1,017 miles at an average speed of 83.69 miles per hour, a list of streamlined high-speed trains, and a bibliography on high-speed trains.

The information contained in these reports and in current time cards relative to high-speed passenger-train schedules leads the subcommittee to assume that its assignment is concerned with average speeds in excess of 75 miles per hour. Such average speeds require cruising speeds of 95 to 105 miles per hour. In any line located or relocated for these high speeds, any curve not capable of a comfortable speed of 100 miles per hour is speed restricting. Comfortable riding in passenger equipment traveling at 100 miles per hour can be provided only on tangent track and on curves of one degree or less. Maximum curvature for operation at 100 miles per hour on located or relocated lines should preferably be 30 min. or less to give greater comfort at present, and to provide for future increases of cruising comfortable speeds of 120 or more miles per hour.

The loss of time resulting from the presence of two speed-limiting curves is illustrated on the profile in Fig. 1. The performance of a locomotive drawing ten light-weight cars is shown by the velocity profile. It will be seen that after 11½ miles over a line of considerable rise and fall, a speed of 97 miles per hour has been attained. Had the curves between MP 48 and MP 51 been one degree or less, the velocity-head profile would have shown continued acceleration until the desired cruising speed of 100 miles per hour had been reached. However, the locomotive engineman, having received warning that he is approaching curves with a speed limit of 70 miles per hour, applies brakes at MP 47.6 and decelerates from 97 miles per hour to 70 miles per hour. Mile Post 61 will have been reached before the locomotive will have attained 100 miles per hour. The time lost because of the speed restriction is ½ min., not important at speeds of 50 to 60 miles per hour, but at 100 miles per hour, if the curves were to be reduced from three degrees to one degree the effect, so far as time is concerned, would be the shortening of the line 0.8 of a mile.

A study for the purpose of comparing the economical operation of two or more located lines over which to operate certain power with certain tonnage can best be advanced by the use of a *method developed by V. I. Smart, formerly special engineer for the Canadian National Railways, and employed to a too limited extent by engineers required to make this determination. By its use, the speed performance of a locomotive and its cars, freight or passenger, can be shown graphically on a location profile by the construction of its velocity profile, which will give directly the speed at every point and and from which elapsed time can easily be calculated from the terminal to any point.

DATA SHEET NO. 1

Speed M.P.H.	*Draw Bar Pull*	*Train Resistance on Level Track*		*Accelerating Force*		*Acceleration Grade Percent*
		Lb. per ton	*Lb.*	*Lb.*	*Lb. per ton*	
0	52,618	3.62	1,810	50,808	60.92	3.05
5	50,558	3.79	1,895	48,663	58.35	2.92
10	46,145	4.00	2,000	44,145	52.93	2.65
15	42,051	4.24	2,120	39,931	47.88	2.39
20	38,610	4.53	2,265	36,345	43.58	2.18
25	35,725	4.85	2,425	33,300	39.93	2.00
30	33,065	5.21	2,605	30,460	36.52	1.83
35	30,770	5.61	2,805	27,965	33.53	1.68
40	28,705	6.05	3,025	25,680	30.79	1.54
45	26,665	6.53	3,265	23,400	28.08	1.40
50	24,755	7.04	3,520	21,235	25.46	1.27
55	22,916	7.60	3,800	19,116	22.92	1.15
60	21,127	8.19	4,095	17,032	20.42	1.02
65	19,515	8.82	4,410	15,105	18.11	0.91
70	18,077	9.49	4,745	13,332	15.99	0.80
75	16,627	10.20	5,100	11,527	13.82	0.69
80	15,256	10.94	5,470	9,786	11.73	0.59
85	13,920	11.73	5,865	8,055	9.66	0.48
90	12,665	12.55	6,275	6,390	7.66	0.38
95	11,538	13.41	6,705	4,833	5.79	0.29
100	10,450	14.31	7,155	3,295	3.95	0.20

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* See Railway Review, February 2, 1924.

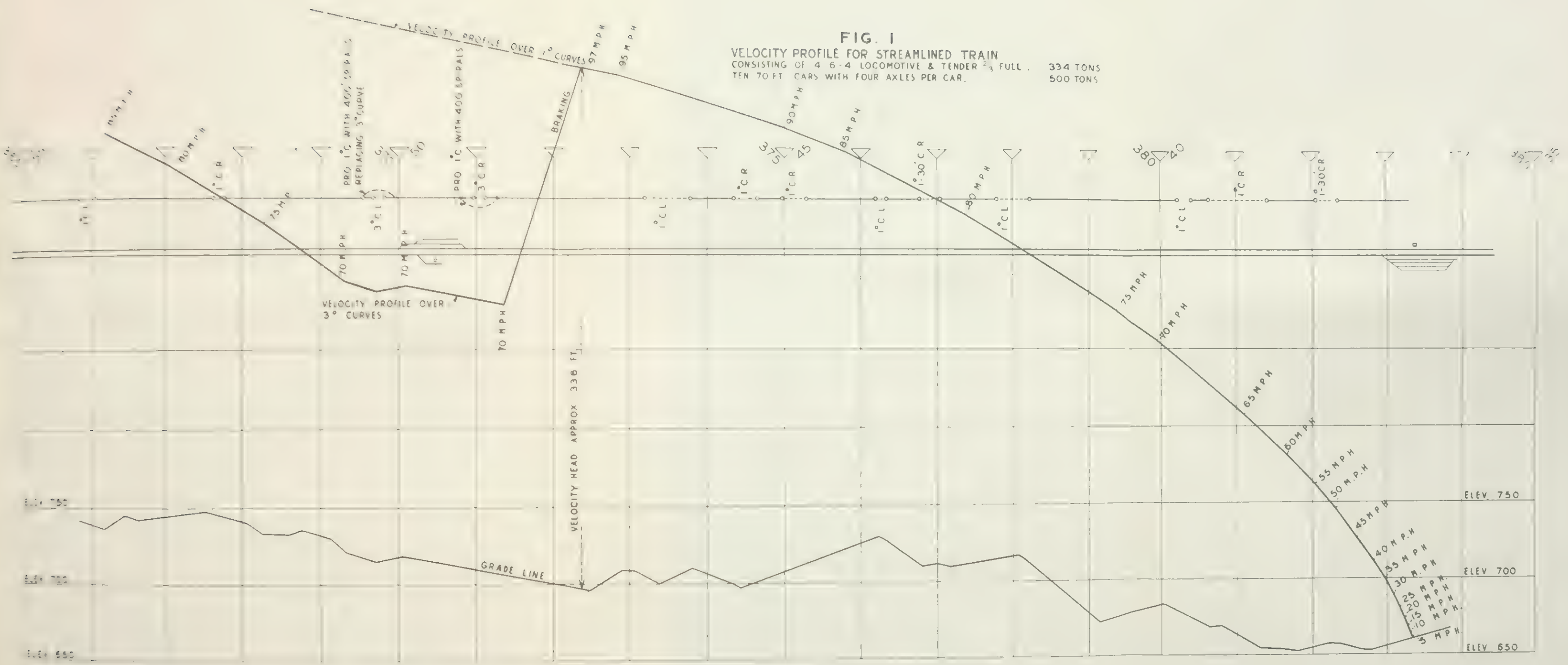
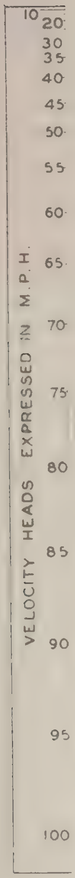


FIG. 1

VELOCITY PROFILE FOR STREAMLINED TRAIN

CONSISTING OF 4 6-4 LOCOMOTIVE & TENDER $^2/_3$ FULL. 334 TONS
TEN 70 FT. CARS WITH FOUR AXLES PER CAR. 500 TONS


VELOCITY HEADS EXPRESSED IN M.P.H.
10
20
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100

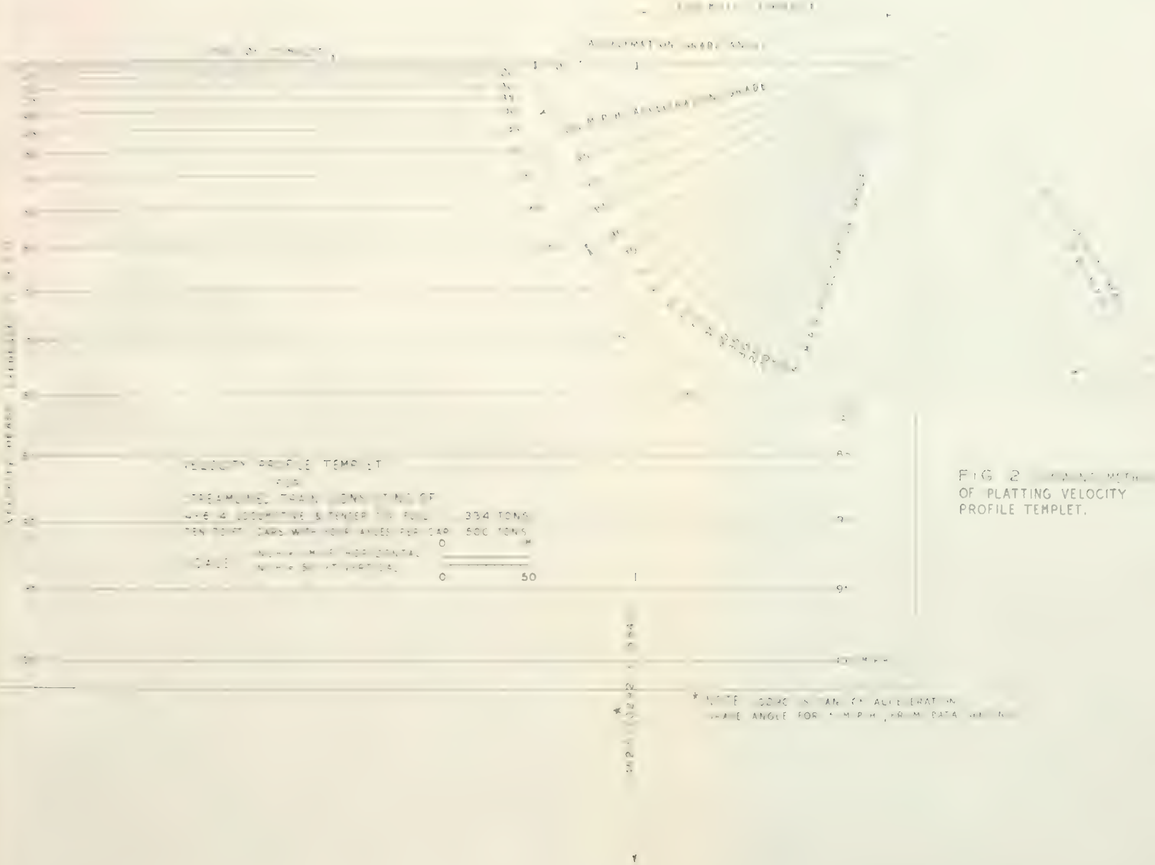
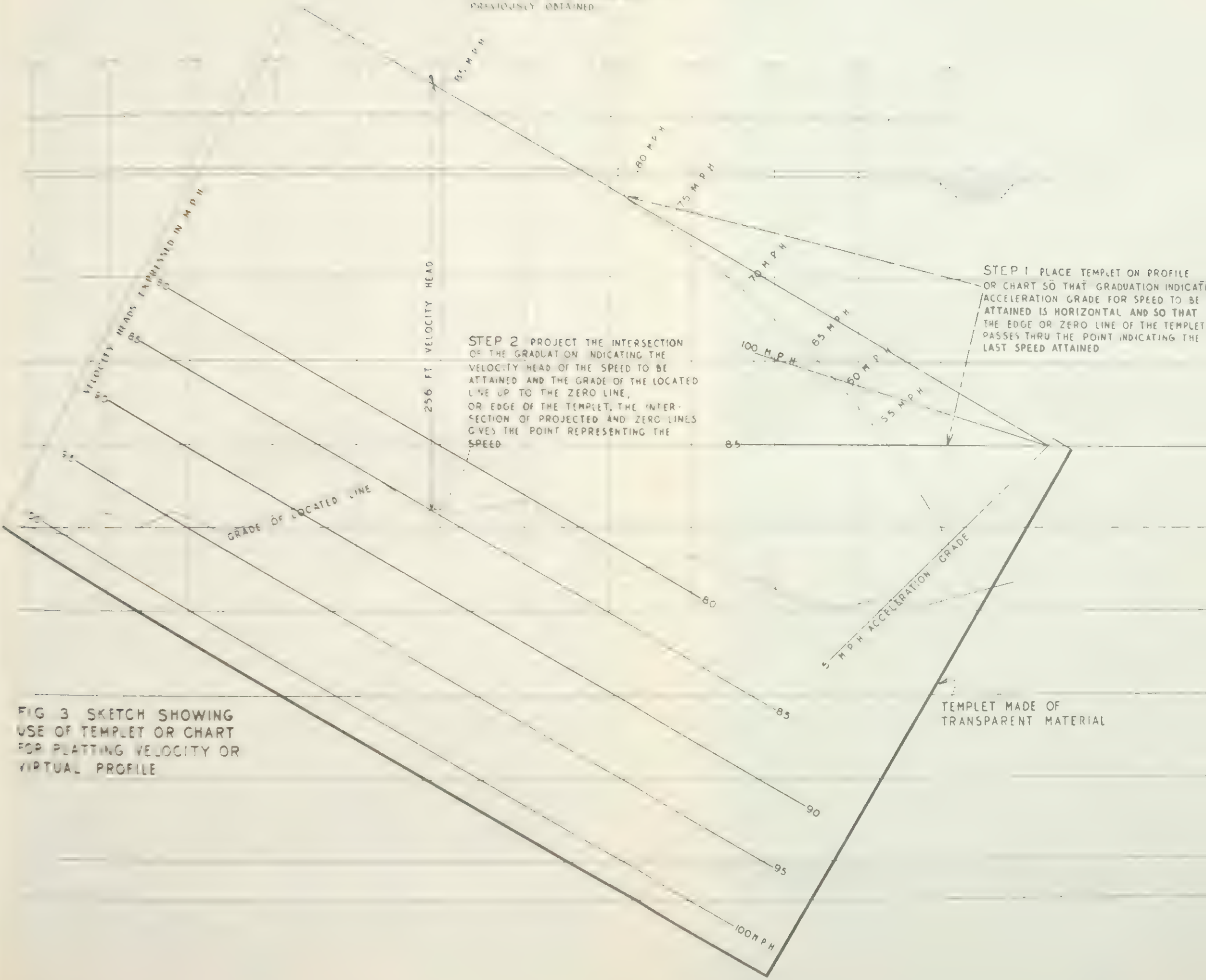

VELOCITY PROFILE TEMPLET
FOR
STREAMLINED TRAIN CONSISTING OF
4-6-4 LOCOMOTIVE & TENDER ... FULL 334 TONS
TEN ... CARS WITH FOUR AXLES PER CAR 500 TONS
SCALE
0
50
M.P.H. ACCELERATION GRADE
* NOTE .0040 IS TAN OF ACCELERATION GRADE ANGLE FOR 1 M.P.H. FROM DATA

FIG. 2 [illegible] METHOD OF PLATTING VELOCITY PROFILE TEMPLET.



STEP 3 DRAW LINE ALONG THE ZERO LINE OR EDGE OF TEMPLET BETWEEN POINT OBTAINED IN STEP 2 AND POINT PREVIOUSLY OBTAINED

STEP 1 PLACE TEMPLET ON PROFILE OR CHART SO THAT GRADUATION INDICATI ACCELERATION GRADE FOR SPEED TO BE ATTAINED IS HORIZONTAL AND SO THAT THE EDGE OR ZERO LINE OF THE TEMPLET PASSES THRU THE POINT INDICATING THE LAST SPEED ATTAINED

STEP 2 PROJECT THE INTERSECTION OF THE GRADUATION INDICATING THE VELOCITY HEAD OF THE SPEED TO BE ATTAINED AND THE GRADE OF THE LOCATED LINE UP TO THE ZERO LINE, OR EDGE OF THE TEMPLET. THE INTERSECTION OF PROJECTED AND ZERO LINES GIVES THE POINT REPRESENTING THE SPEED

TEMPLET MADE OF TRANSPARENT MATERIAL

FIG 3 SKETCH SHOWING USE OF TEMPLET OR CHART FOR PLATTING VELOCITY OR VIRTUAL PROFILE

The templets, scales and formulas, included in this report, are useful supplements to Mr. Smart's method.

When the velocity profile is drawn on the engineering profile of two or more located lines between the same terminals, and the engineer has before him thereby a comparison of the performance of the same locomotive and loading on each, the merits of the method become apparent. Also, as the drawing of the velocity profile progresses, if the speed on ascending grades is seen to be in excess of that determined upon for that line, changes may be made in the grades which will materially reduce the cost of construction.

Data Sheet No. 1 is first prepared. The draw-bar pull (tractive effort less locomotive resistance) must be found from dynamometer tests or calculated as recommended in AREA Proceedings and Manual.

For the purpose of constructing a velocity profile for a given locomotive and loading, it will be found convenient to reduce all resistances to equivalent rates of grade by dividing the resistance per ton by 20; see two right-hand columns of the Data Sheet No. 1.

Proceeding to plat the velocity-head profile, a line is drawn above the engineering profile rising at the rate of 2.92 percent from the horizontal. (Assuming that velocity grade is a straight line from 0 to 5 miles per hour, the velocity grade for five miles per hour is platted from the starting point and continued until a velocity head equal to five miles per hour is reached, i.e., until the velocity grade is vertically above the grade line, a distance equal to the velocity head for five miles per hour). Its length is to a point 0.89 of a foot above the grade line of the location profile. From this point, a grade of 2.65 percent (5 miles per hour to 10 miles per hour) is platted from a horizontal line, and its length is fixed by a point 3.55ft. (velocity head for 10 miles per hour) above the grade line of the location profile. This method is continued until the cruising speed is reached, or to a point where braking or drifting becomes necessary.

Fig. 1 was prepared to illustrate the platting of a velocity profile on a condensed grade line of the location profile. The start was made on a 0.30 percent descending grade; the 2.92 percent grade was platted from a horizontal line until the vertical distance between the velocity profile and the actual grade line is 0.89 of a foot, the velocity head for five miles per hour. The velocity grade must always be platted from a horizontal line.

Fig. 2 is shown as an example of a templet that was developed to expedite the platting of the velocity grade. Using such a templet, it is not difficult to plat velocity grade over 50 miles of engineering profile in one day. It is necessary to make a similar templet for the performance of each locomotive and tonnage under study for operation on the located line.

The templet is to be made of transparent material such as celluloid so that the lines of the engineering profile may be seen through the templet, thereby simplifying the operation of placing the acceleration grade of the templet along a horizontal line of the engineering profile.

The scale of the templet, horizontal and vertical, must conform to the scale of the profile of the located line. Usually only the engineering profile is available for located lines and has been most frequently used for platting velocity grades. However, a condensed profile, which is drawn to scale, will be satisfactory for use in platting velocity grades if the templet is made to conform to the scale of the condensed profile.

Fig. 3 was prepared to show how the templet is superimposed on the location profile in the construction of the velocity profile. The velocity profile is about to be drawn between 80 miles per hour and 85 miles per hour. The 85 miles per hour acceleration grade line of the templet is placed on a horizontal line of the engineering profile and

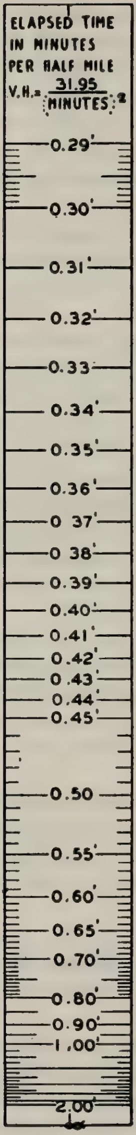


FIG. 4 - SCALE FOR READING ELAPSED TIME FROM VELOCITY PROFILES.

GRADUATIONS INDICATE FEET OF VELOCITY HEAD EXPRESSED IN MINUTES OF ELAPSED TIME.

FORMULA $V.H. = \frac{31.95}{(\text{MINUTES})^2}$

$V.H.$ = VELOCITY HEAD IN FEET $= .0355\,V^2$

V = VELOCITY IN M.P.H. $= \frac{\text{MILES}}{\text{HOURS}}$. THEN,

$$V.H. = \frac{.0355\,(\text{MILES})^2}{(\text{HOURS})^2}$$

IF THE TIME IS READ EACH HALF MILE AND THE THE TIME EXPRESSED IN MINUTES, THE FORMULA BECOMES

$$V.H = \frac{(.0355)\,(0.50)^2\,(60)^2}{(\text{MINUTES})^2} = \frac{31.95}{(\text{MINUTES})^2}$$

moved to the right or left until the ruling edge of templet passes through the 80-miles-per-hour point. The notes on the templet indicate the sequence for completing the velocity profile to the 85 miles per hour point.

Fig. 4 is a scale, the purpose of which is to measure the time required to negotiate each mile and, by simply summing the reading, to arrive at elapsed time. This scale must be made to fit the vertical scale of the profile being used, using the formula therefor shown at the top of the scale.

The braking resistance should be reduced to equivalent grade by dividing the resistance in pounds per ton by 20. For high-speed trains, braking tests in increments of five miles per hour up to the maximum speed of the train are advised for the purpose of determining the total distance traveled in making the stop, as well as the distances traveled between each reduction of five miles per hour in the speed. Drifting equivalent grade may be found by dividing resistance of the train at each five miles per hour by 20.

The subcommittee recommends that this report be received as information and the subject continued.

Appendix K

(12) Grades and Alinement Through Tunnels

F. N. Nye (chairman, subcommittee), J. L. Campbell, J. L. Haugh, C. H. R. Howe, Wm. Michel, L. G. Morphy, H. M. Shepard, C. B. Stanton, W. D. Wiggins, S. L. Wonson.

Foreword

Since the publication of the previous report of this subcommittee on pages 508–510 of Vol. 39 of the Proceedings, a comprehensive questionnaire, designed to elecit information covering the problem of tunnel location, the relation of the tunnel to other parts of the railway line, and also certain conditions of operation through tunnels, was addressed to chief engineers of the major railroads of the United States, Canada and Mexico. The response to this questionnaire has been very satisfactory and there is appended to this report a tabulation of data resulting therefrom, which it is believed covers all tunnels having a length of 1,000 ft. or more in the United States and Canada, together with many such tunnels located in Mexico.

This tabulation covers some 433 tunnels located on 53 railways, and certain features of it will be briefly abstracted. Throughout this report the term "tunnel roads" will refer to those roads having one or more tunnels of 1,000 ft. or more in length, and the term "tunnels" will refer to those over 1,000 ft. long.

Regional Distribution of Tunnels

Responses to the questionnaire revealed that such tunnels and tunnel roads were distributed as follows:

New England region	2	tunnel	roads,	operating	through	4	tunnels
Great Lakes region	12	“	“	“	“	46	“
Central Eastern region	6	“	“	“	“	81	“
Pocahontas region	3	“	“	“	“	46	“
Southern region	7	“	“	“	“	63	“
Northwestern region	6	“	“	“	“	47	“
Central Western region	10	“	“	“	“	107	“
Southwestern region	3	“	“	“	“	9	“
Canadian roads	2	“	“	“	“	21	“
Mexican roads	2	“	“	“	“	9	“
Total	53					433	“

Principal Distribution Among Railways

Among the tunnel railroads on the North American continent the following are outstanding:

Railway	*No. of Tunnels Over 1,000 ft. Long*	*Aggregate Length in Feet*
Southern Pacific	50	127,632
Baltimore & Ohio	37	81,324
Pennsylvania	30	97,246
Great Northern	17	78,286
Canadian Pacific	11	52,494
Louisville & Nashville	25	48,512
Norfolk & Western	21	43,801
Chesapeake & Ohio	15	48,242
New York Central System	17	49,359
Southern	16	32,167
Chicago, Milwaukee, St. Paul & Pacific	13	39,044
Denver & Salt Lake	7	41,189
Canadian National	10	36,846
Clinchfield	14	29,203
Union Pacific	13	28,152
Western Pacific	11	32,966
Northern Pacific	8	26,500
Virginian	10	18,520
Boston & Maine	1	25,081

These roads, some 36 percent of all the tunnel roads, include 75 percent of the tunnels, aggregating 79 percent of the total length. They average 17 tunnels each, which in turn have an average length of 2,870 ft. The remaining tunnel railroads average only 3 tunnels each and these in turn have an average length of 2,320 ft.

Classification as to Tunnel Length

The aggregate length of all tunnels studied was about 225 miles, or less than 0.1 percent of the total railroad mileage in North America. The average length of all such tunnels was 2,740 ft., distributed among the following groups:

Length Classification	*Number of Tunnels*
10,000 ft. or over	10
9,000 ft.—10,000 ft.	1
8,000 ft.— 9,000 ft.	2
7,000 ft.— 8,000 ft.	4
6,000 ft.— 7,000 ft.	10
5,000 ft.— 6,000 ft.	11
4,000 ft.— 5,000 ft.	31
3,000 ft.— 4,000 ft.	39
2,000 ft.— 3,000 ft.	75
1,000 ft.— 2,000 ft.	250
0 ft.— 1,000 ft.	(not included in study)
Total	433

Notable Tunnels

The ten longest tunnels on the North American continent are of sufficient interest in themselves to be segregated and examined as to certain characteristics.

Tunnel	*Railway*	*Length feet*	*Trks.*	*Electrified*	*Mech. Vent.*	*Alinement*	*Percent Grade*
Cascade	Great Northern	41,152	1	Yes	No	Tangent	+1.57 E.B.
Moffat	Denver & Salt Lake	32,798	1	No	Yes	Tangent	+0.3 to —0.9 W.B.
Connaught	Canadian Pacific	26,518	2	No	Yes	Generally Tangent	+0.95W.B.
Hoosac	Boston & Maine	25,081	2	Yes	Yes	Tangent	+0.5 to —0.5 E.B.
Mount Royal	Canadian National	16,645	2	Yes	No	Generally Tangent	+0.6 W.B.
Hudson River	Pennsylvania	15,600	2	Yes	Yes	Curved	—1.9 to +1.3 W.B.
East River	Pennsylvania	14,172	4	Yes	Yes	Curved	—1.5 to +1.5 E.B.
Snoqualmie	Chi. Mil. St. P. & Pac.	11,890	1	Yes	No	Curved	—0.4 W.B.
Park Avenue	New York Central	10,440	4	Yes	No	Tangent	Max. +1.02 N.B.
Norden	Southern Pacific	10,326	1	No	No	Tangent	—1.47 E.B.

It is interesting to note that while the Cascade tunnel is the longest in North America, it is exceeded in length by five railway tunnels in Europe, namely: Simplon (64,971 ft.); Etruscan Appenine Tunnel (60,720 ft.); St. Gothard (48,927 ft.); Loetschberg (47,685 ft.); and Mt. Cenis (42,150 ft.).

Double-Tracked Tunnels

Out of the 433 tunnels reported to the subcommittee, there are 105, or about 25 percent of the total which are double-tracked (or, in a very few instances, four tracked). These tunnels aggregate about 29 percent of the total length of all tunnels included in the study. They are located on 29 different railways, with the Pennsylvania and the Baltimore & Ohio outstanding in the operation of double-tracked tunnels.

Tunnel Linings

Returns to the questionnaire disclosed that about

40 percent of the tunnels were lined with concrete
20 percent of the tunnels were lined with brick and/or stone
12 percent of the tunnels were lined with timber
18 percent of the tunnels were lined with combinations of the above
8 percent of the tunnels were unlined

The remaining 2 percent of the tunnels were not fully described as to lining.

Grades and Alinement Through Tunnels

With respect to grades the tunnels are grouped thus:

On level grade	2 percent of the tunnels, including such a long one as the 6,994-ft. Edgewood Tunnel No. 2 on the Illinois Central
Grades of 1 percent or less	72 percent of the tunnels
Grades of 1 percent to 2 percent	23 percent of the tunnels
Grades over 2 percent	3 percent of the tunnels; practically all of these heavy-grade tunnels are on western roads and in mountain territory

As to alinement, the groupings are as follows:

Tangent throughout	51 percent of the tunnels
With curvature less than five degrees	22 percent of the tunnels
With curvature five degrees and over	27 percent of the tunnels

Combinations of grade and alinement vary from level and tangent, as for instance on Tunnel No. 7 of the Ferrocarriles Sud Pacifico de Mexico, where drainage was not a factor, to the spiral tunnels of the Canadian Pacific Railway in which loop curves for development to gain elevation enter the side of the mountain on a 10 deg. alinement and a 1.62 percent grade (which is the ruling grade of 2.2 percent, compensated 0.04 percent per degree of curvature, plus an arbitrary 0.2 percent for anticipated adverse rail conditions). While the grades and curvature of these tunnels are not the maximum, their combination in the same tunnel, involving such a large central angle and the ruling grade, represents an extreme condition. It is reported that locomotives are worked to capacity through these tunnels and that they are not restrictive. Between these extremes lie hundreds of combinations of grades and alinement as roughly classified above.

Relatively few of the tunnels are located on ruling grades and of such tunnels on ruling grades about one quarter have the ruling grades reduced through the tunnel from about 5 percent to 50 percent. However, very few of the tunnels in which the grade was not reduced have been reported as restrictive of present operations, although it is possible that some might well be restrictive of expanded operations. About one-fifth of the tunnels are summit tunnels (or under-river tunnels), which, it should be noted, are frequently unsatisfactory from the standpoint of ventilation, although generally easier to drain during construction.

Electrified Tunnels

Eleven roads operate by electric power through some 40 tunnels having an aggregate length of about 45 miles and an average length of about 6,000 ft. each. These range in length from 1,000 ft. to 41,152 ft., and from single-track to four-tracked tunnels. The principal railroad with electrified tunnel operations is the Pennsylvania.

Ventilation of Tunnels

Twelve roads reported some 22 tunnels which are mechanically ventilated, 8 of which were double-tracked tunnels. They ranged from 2,021 to 32,798 ft. in length with an average of about 8,400 ft. Also reported are 25 tunnels which are naturally ventilated through one or more shafts. The remaining 90 percent of the tunnels are ventilated only through the portals without mechanical equipment. These include many steam-operated tunnels more than 4,000 ft. in length, in which conditions are reported as satisfactory.

Restrictive Tunnels

Nine railways reported on 21 restrictive tunnels, but of these, less than half are restrictive because of grade or alinement within the tunnel.

New Construction

In addition to requesting the information concerning these various tunnels, each chief engineer was asked this question: "On new construction, what change in the rate of grade, if any, is advisable in your opinion, where the tunnel is located on a ruling grade?" Their replies are summed up as follows:

16 Chief engineers whose roads include 90 tunnels were non-commital
15 Chief engineers whose roads include 111 tunnels recommended no reduction
22 Chief engineers whose roads include 232 tunnels conceded the desirability of grade reduction and their recommendations in brief are—

A—The chief engineer of a large road in the Greate Lakes region felt that a reduction while desirable, would ordinarily cost more than the capitalized savings resulting.

B—Officers of other roads, scattered throughout the country, while recognizing the desirability of reducing such a tunnel grade, felt that it depended on so many local conditions that the extent thereof could not be expressed in a single recommendation.

C—Engineers of numerous roads recommended more specific reductions, but qualified such recommendations in some instances. These recommendations are:

(Note: Figures in parenthesis indicate number of 1,000-ft. or longer tunnels on each road.)

Great Lakes Region

Erie (3) Recommended 25 percent reduction.

New York Central (Lines West) (4) believed 25 percent reduction to be reasonable.

Central Eastern Region

Pennsylvania (30) believed 1 percent grade through tunnel to be desirable maximum.

Western Maryland (7) believed 1 percent grade through tunnel to be desirable maximum.

Pocohontas Region

Chesapeake & Ohio (15) favored as much reduction as possible.

Norfolk & Western (21) would endeavor to hold tunnel grades to 0.3 percent.

Southern Region

Louisville & Nashville (25) recommended compensating such gradients by 0.2 percent.

Seaboard Air Line (1) recommended compensating such gradients by 0.3 percent.

Northwestern Region

Chicago Great Western (1) recommended 10 percent reduction.

Central Western Region

Atchison, Topeka & Santa Fe (4) recommended flattening of summit grades.

Chicago, Rock Island & Pacific (2) recommended tunnel grades be as low as economically possible.

Chicago, Burlington & Quincy (3) recommended 20 to 25 percent reduction and for a train length beyond the lower end.

Southern Pacific System (62) recommended, if tunnel is on a ruling grade, a compensation of 0.5 percent be made for each 1,000 ft. length of tunnel.

Western Pacific (11) recommended ruling grade through tunnel be reduced 40 percent, but that a minimum grade of 0.3 percent be maintained for adequate drainage.

Southwestern Region

Missouri Pacific (6) recommended compensating such gradients 0.1 percent.

Terminal Railroad Association of St. Louis (1) recommended use of minimum grades.

Canada

Canadian Pacific (11) believed 25 percent reduction is ample.

The Cascade Tunnel

Your subcommittee, in addition to studying the tunnel data received in answer to its questionnaire and giving particular consideration to the recommendations of the chief engineers of the various tunnel roads, has studied the circumstances attending the location and design of the Great Northern Railway's Cascade tunnel.

It is believed that the entire subject of the economics of railway location and operation, as well as the particular assignment of the subcommittee is so well epitomized in this single project, that a brief description of it would be appropriate in this report. The committee quotes from a report published in 1930 by the National Electric Light Association in connection with electrification on that line.

In 1893 the Great Northern Railway completed its Pacific Coast extension from Havre, Mont., to Seattle, Wash. The line was located under definite instructions to penetrate the northern part of the United States—then unsettled and devoid of railroad facilities—with the shortest possible low-grade line.

The route was established with only two mountain crossings, one in the Rocky mountains and one in the Cascade range. The first was through Marias pass near the southeast corner of the present Glacier National park, the second through Stevens pass, a little east of Skykomish, Wash. Marias pass has proved to be the lowest in the Rockies north of New Mexico. The Great Northern here reaches the maximum altitude of its line at 5,211 ft. The grades are also favorable. The maximum westbound is only 1.0 percent while the ruling grade eastbound (against heavier traffic) is 0.8 percent, with a 1.8-percent helper district 13 miles in length.

In the Cascades the passes are generally lower than in the Rockies but the mountain sides are steep and rugged so that tunnels are usually necessary. The line across the Cascades was established with a maximum gradient of 2.2 percent, except for a few miles at the top of the mountain. Here it went across the floor of Stevens pass at an altitude of 4,059 ft., with switchbacks on either side of the pass having grades of 3.5 and 4.0 percent. There were several locations where a tunnel might be built later, when the railroad had established its business. Trains were operated over the summit for seven years with a great deal of difficulty due to eight reversals, hand braking, heavy grades, and a severe winter climate. Only a few cars could be handled with an engine at each end and the switchbacks were consequently eliminated as soon as possible.

THE FIRST CASCADE TUNNEL

In 1900 the first Cascade tunnel was ready for duty between the mountain stations of Tye and Cascade tunnel. The length was 13,873 ft. (2.63 miles), on a tangent and with a uniform grade of 1.69 percent rising from west to east. The gradient on both sides of the mountain, however, was 2.2 percent for several miles below the portals. This tunnel and approaches totaled 3.52 miles and replaced 12.66 miles of switchback line. It also reduced the altitude to 3,382 ft., a saving of nearly 700 ft.

It was not long before this tunnel became the limiting feature of the whole line. The gradient of 1.69 percent opposed the heaviest movement of traffic, and with steam locomotives conditions were so difficult that it was decided to electrify the tunnel. The obstacles to steam operation were concisely explained by the consulting engineer in charge of the electrification as follows:

"The operation of the tunnel with steam locomotives was at all times difficult and frequently very dangerous on account of the heat and smoke from locomotives . . . The rails became very wet from condensed steam, and were frequently covered with a layer of coal soot and ground sand making them very slippery. Under ordinary circumstances it required from 20 min. to an hour for the tunnel to clear itself of gases, but on days when the wind was changeable, the passage of the gases from the tunnel would be stopped by the change in the direction of the wind, and they would pocket.

"Trains eastbound from the Pacific coast were from 1,400 to 1,500 tons trailing load with two Mallet compound engines. At the west end of the tunnel at the foot of the grade, all trains were stopped, fires were hauled and cleaned, the engines took on a special high-grade coal, new fires were built and the engines remained in the yard for an hour or more, coking these fires in order to get rid of superfluous gas. In addition, a helper engine was kept in the yard, which used the same grade of coal and with the same precautions. The train was divided into two parts, the helper engine taking about 400 tons through and the two Mallet engines afterwards taking the remainder of the train, say 1,000 tons.

"When weather conditions were bad it was almost impossible to get trains through the tunnel; sometimes it was necessary to wait two or three hours after the passage of one train before it was safe to send a second train through. Frequently the steam pressure in the rear Mallet engine would fall from 200 lb. to 70 lb. or less, owing to the impossibility of maintaining fires on account of the exhausted conditions of the air in the tunnel. The train would then have to stop and be split into two sections, and it would be necessary to back the rear engine out with part of the train."

To remedy these conditions, the Cascade tunnel was electrified in 1909. The three-phase system was chosen for its simplicity and automatic regeneration. On the tunnel section with 1.69 percent grade, three locomotives could haul 2,500 tons. This included the weight of one Mallet steam locomotive, as the distance was too short to detach the steam power. This tonnage was a marked improvement over the previous loads that had been handled through the tunnel, namely, 1,000 tons.

THE NEW TUNNEL AND LINE CHANGES

When the line was built across the Cascades, the mountains were heavily wooded and gave no evidence of snowslides. After the railroad had been in operation for several years, forest fires consumed much of the timber from adjacent slopes and snowslides became serious. A few years after the building of the first Cascade tunnel, the railroad was forced to make a heavy investment for protection against these slides, and thereafter had to spend large sums of money every year.

The operating difficulties experienced over the old line, particularly during the winter, caused studies to be made, as early as 1915, of new routes which would avoid snowslides, give a lower summit, and reduce the mileage. These studies resulted in serious consideration being given to four routes involving tunnels ranging from 6 to 17 miles. The World war stopped these studies for a while. Afterwards consideration was given to the subject intermittently until plans for a new tunnel were finally adopted in November, 1925. At that time, it was decided to undertake, at a total cost of about $25,000,000:

1. Construction of a tunnel, 7.79 miles in length, between Scenic and Berne.
2. Relocation of the line, on 19 miles of new right-of-way, on the east slope of the Cascades between Peshastin and Winton.
3. Revision of the line for several miles between Winton and Berne.
4. Electrification of the whole mountain crossing, including the new tunnel, between Appleyard (Wenatchee) and Skykomish, a distance of 73 miles.

The complete plan was designed to bring this section up to the company's standard for the remainder of the line between Puget sound and St. Paul.

Work was commenced on the new improvements in December, 1925, and they were all completed in January, 1929. The tunnel passes through the mountain between the stations of Scenic and Berne, joining the old line near both portals. It is a single-track tunnel 7.79 miles long, through solid rock and lined with concrete throughout. The tunnel is on a tangent and has a uniform grade of 1.56 percent ascending from west to east. The summit is just outside the east portal. This tunnel eliminates a large amount of maximum grade on both sides of the mountain, also a great deal of curvature and several miles of snow sheds.

The line revision on the east side of the mountain included 19 miles of new construction between Peshastin and Winton on which three tunnels were located. The new line follows Chumstick creek for about six miles, crosses the Wenatchee river, and joins the old line at Winton near the upper end of the Tumwater canyon. The old line was improved much of the remaining way from Winton to the portal of the new tunnel at Berne.

The combined result of the new tunnel and the new line has been to eliminate 8.9 miles of line, 502 ft. of elevation, 112 curves, 3,674 deg. of curvature, 24 miles of maximum 2.2 percent grade, and nearly 40,000 ft. of snow sheds. The line is no longer menaced by heavy slides, and less than 1,000 ft. of snow sheds have to be maintained. On the east side of the mountain there still remain about 5.5 miles of 2.2 percent grade, and on the west side about 10.5 miles, between Skykomish and Berne. This is the maximum gradient of the entire line, but no longer a formidable obstacle.

It is difficult to make a precise comparison of the old and new lines of the Great Northern through the Cascades on account of the modern electrification installed in connection therewith, but it is safe to say that the line revision would have greatly facilitated steam operation were it practicable to use steam locomotives in the new tunnel nearly 8 miles long. In preparing its plans the railway figured that it would make a satisfactory saving from the whole investment in tunnel, realinement and electrification.

It also anticipated and subsequently realized a substantial increase in train weights and speeds and an increase in traffic attracted to the line.

Discussion

The desirability of easy gradients is universally conceded, and the necessity for this is greater in tunnels than on open railway line. The reasons for this are self evident and are in part as follows:

1. Reduced traction because of soot and condensed moisture, or drip on rails. Unless the gradients are moderate excessive sanding will be required, fouling ballast and drainage channels and increasing maintenance costs.
2. Hazard to train crews and livestock shipments from hot engine gases if the grade requires capacity locomotive effort.
3. Decrease in rate of combustion and loss of steam pressure in smallbore tunnels, especially when double heading, may result in stalling with its attending hazards.
4. Difficulty of grade revision through tunnels frequently makes restrictive tunnels a permanent limitation to the potential capacity of the line and discourages grade revision elsewhere.
5. Track resistance is frequently greater due to difficulties of maintenance work in tunnels.
6. Excessive air resistance where the bore is restricted or when moving against ventilating currents.

The desirability of tangent alinement or flat curvature is also universally conceded and the necessity for this also is greater in tunnels than elsewhere because such alinement:

(a) increases the engineman's sight distance and promotes safety,
(b) aids ventilation,
(c) requires no compensation for curvature and permits what grade reduction can be secured to become fully effective,
(d) makes for easier and safer track maintenance.

For these reasons, if for no others, it is believed that in all new tunnel design and location serious consideration should always be given to the economics of reducing the proposed grade through the tunnel to something less than the ruling grade.

A study of the operating conditions through a proposed tunnel will probably reveal that certain economies or operating advantages will accrue if such a reduction is made.

While a reduction of ruling grades through proposed tunnels of 25 percent or even more may, and frequently would be, justified, each case must be considered on its individual characteristics, as no single rule can be laid down as to whether the capitalized savings, or other advantages resulting from operating on the reduced tunnel gradient, would justify the additional capital expenditure to secure that gradient.

With concrete lined tunnels of ample cross section, well drained and ventilated, such as are now generally designed for lines with heavy traffic, the necessity for grade reduction diminishes, and as operating and maintenance conditions within the tunnel approximate those outside it may even vanish. It is possible that a study of individual cases will indicate that greater benefits may be anticipated from an expenditure to enlarge the tunnel sections, or to improve the ventilation, than from a similar expenditure to reduce the grade.

The committee has, therefore, reached the following conclusions, which are intended to supersede those published in the Proceedings for 1938, Vol. 39, page 510, although they do not differ greatly from the conclusions previously offered.

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TUNNEL	LOCATION	Length	Trks	Hght.	Width	LINING	THROUGH TUNNEL GRADES	THROUGH TUNNEL ALIGNMENT	Reduction of Rul. On	Ruling Grade	Max. Curvature	Dir. of Traf.	Wgt. Hviest Trains	Type & Tractive Power Operated	Ventilation
NEW	ENGLAND	REGION.				BOSTON	AND	MAINE							
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Tangent	[illegible]	[illegible]	8°40'	East	6500	2-[illegible]-2 71,300* + 3,200*	Mech.
						NEW YORK, NEW	HAVEN &	HARTFORD							
[illegible]	[illegible]	[illegible]	2	[illegible]	30'	Stone & Brick	[illegible] EB	Tangent	Not on	+0.[illegible] EB	6°00'	East	5000	4-8-2 71,000*	Shafts
[illegible]	[illegible]	[illegible]	2	[illegible]	30'	[illegible]	[illegible] WB	Tangent & 8°00'	Not on	+1.3[illegible] WB	7°00'	East	900	2-6-0 25,257*	Portal
[illegible]	[illegible]	[illegible]	2	[illegible]	33'	[illegible]	[illegible] WB	Tangent	[illegible]	+0.[illegible] EB	4°00'	East	4000	2 (2-10-2) 77,800*	Portal
GREAT	LAKES	REGION				DELAWARE	AND	HUDSON							
[illegible]	[illegible], N.Y.	2234	1	[illegible]	17'5"	Stone & Brick	[illegible] WB	Tangent & 4°00'		[illegible]	7°15	North	3750	2-8-0 72,700*	Shaft
						DELAWARE LACKAWANNA		& WESTERN							
[illegible]	Hoboken, N.J	[illegible]	2	[illegible]	[illegible]	Partly Brick	[illegible] WB	Tangent	Not on	+0.55%	9°00'	East	6800	4-8-2 77,600*	Shafts
[illegible]	[illegible], N.J	[illegible]	2	[illegible]	30	Concrete	[illegible] WB	Tangent	Not on	+0.55%	9°00'	East	6800	"	Shafts
Oxford	[illegible]	[illegible]	1	[illegible]	[illegible]	Partly Concrete	+0.15%, [illegible] WB	Tangent & 3°15'	Not on	+0.55%	9°00'	East		"	Portal
[illegible]	[illegible], N.J	[illegible]	2	[illegible]	30'	Partly Concrete	+0.55% EB	Tangent	None	+0.55%	9°00	East	6800	"	Portal
[illegible]	[illegible], Pa	3629	2	[illegible]	29.9	Brick	+0.15% WB	Tangent	Not on	+1.46%	8°00'	East	5775	"	Shafts
							ERIE								
[illegible]	[illegible], N.Y.	[illegible]	2	23	30	Partly Conc & Br	+0.15%, [illegible] EB	Tangent	0.05%	+0.22% EB +0.6% WB		East	7200	2-8-4 72,000*	Shaft
Bergen	[illegible], N.J	4161	2	[illegible]	28	Partly Brick	+0.186% WB	Tangent	Not on	Tunnel located in Terminal Area					shafts
[illegible]	[illegible], N.J	5065	2	19	27'	Partly Brick	+0.36% WB	Tangent	Not on	"	"		"	" "	shaft
						LEHIGH	AND NEW	ENGLAND							
[illegible]	Lansford, Pa	[illegible]	1	[illegible]	11'	Partly Br & Tmr	[illegible] EB	Tangent	Not on	+1.14%	12°00'	E&W	2800	0-8-0 68,500*	Shaft
						LEHIGH		VALLEY							
[illegible]	[illegible], N.J	4833	2	25	30'	Concrete	+0.20%, -0.18% EB	Tangent	Not on	0.30%	7°02'	East	9000	2-8-2 63,000*+14,400*	Portal
[illegible]	[illegible]	1196	2	[illegible]	26		+0.52% WB	5°20'	Not on	1.30%	10°30'	East	1600	2-10-2 72,620*	Portal
[illegible]	Tunkhannock Pa	3902	2	[illegible]	25'		+0.11% WB	Tangent & 5°30'	Not on	0.20%	5°30'	East	6200	4-8-4 66,400* 18,000*	Portal
						MICHIGAN		CENTRAL							
Detroit River	Detroit Mich	8390	2				-20%, +15% EB	2°00' T, 2°00'				East		Electric 39,100*	
						NEW	YORK	CENTRAL							
Park Ave	G.C.T. New York	[illegible]440	4	[illegible]	[illegible]	Brick & Stone	Max +1.02% WB	Tangent	None	WB +1.02%	7°15	E&W	1200	Electric 62,800*	Shafts
St Marys	Melrose, NYC	906	2	16'	26	Concrete	Level	Tangent & 6°00'	Not on	+0.25%	17°00'	East	3500	Electric (88,500*) 2	Shafts
Weehawken	Weehawken N J	4222	2	6	26	Miscellaneous	+0.3[illegible]% -0.36% EB	Tangent & 12°-30	Not on	+0.52%	9°-30'	East	4500	H-5 (48,570*) 2	Mech.
Haverstraw	Haverstraw NY	1678	2	[illegible]	26	Partly Concrete	+0.52% EB	Tangent & 5°00'	None	+0.52%	9°-30'	East	4500	"	Portal
West Point	West Point NY	2740	2	16'	26	Miscellaneous	Level, -0.3% EB	Tangent & 4°00'	Not on	0.52%	9°30'	East	4500	"	Portal
Cazenovia	Cazenovia NY	1631	1	6	16	Miscellaneous	+1.39% EB	Tangent	Not on	+1.72% EB	5°00'	East	1000	E-1 31,730*	Portal
Peale	Peale, Pa	1277	1	17'	16'	Miscellaneous	+0.75% EB	Tangent	Not on	+1.5% EB	12°00'	East	1100	H-6 66,230*	Portal
Karthaus	Karthaus Pa	431	1	20	15'	Miscellaneous	-0.30% EB	6°00'	Not on	+0.35% EB	6°30'	East	10,000	L-2 73,020*	Portal
Deer	Frenchville, Pa	1151	1	20	16	Concrete	-0.20% EB	6°00'	Not on	+0.35% EB	6°30'	East	10,000	L-2 73,020*	Portal
Shawsville	Shawsville Pa	1792	1	19	15'	Concrete	-0.20% EB	Tangent & 6°00'	Not on	+0.35% EB	6°30'	East	10,000	L-2 73,020*	Portal
Fulton	Clearfield Pa	2716	1	20'	14'	Partly Concrete	-0.20% EB	Tangent & 6°00'	Not on	+0.35% EB	6°30'	East	10,000	L-2 73,020*	Portal
No 2	Dix, Pa	2183	2	22-6	29'	Conc & Brick	+0.23% EB	Tangent							Portal
No 3	Dix. Pa	1739	2	22'6'	29'	Conc & Brick	+0.23% EB	Tangent							Portal
Moxahala	Moxahala, Ohio	1275	1	21'10"	17'3"	Concrete	+0.52%, -0.6% SB	5°54' T, 4°00'							Shafts
Koontz Bend	Swiss, W Va	3163	1	22'4	18'	Concrete	+0.82% SB	Tangent	0.18%	1.00%					Portal
						PITTSBURG	AND LAKE	ERIE							
J & L.	Pittsburgh, Pa	1625	2	16'	24'	Miscellaneous	Level	Tangent & 2°00'	Not on	0.30%	10°48'	West	9500	2-8-2 63,500*+11,200*	Portal

Legend

Conc.	= Concrete		EB	=	Eastbound
Br.	= Brick		WB	=	Westbound
Timb.	= Timber		T	=	Tangent
Misc.	= Combinations of above		Mech.	=	Mechanical

The ruling grade and maximum curvature are for operating Division on which Tunnel is located; direction of traffic refers to greater volume.

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TUNNEL	LOCATION	Length	Trks	Height	Width	LINING	THROUGH TUNNEL GRADES	THROUGH TUNNEL ALIGNMENT	Reduction of Rul.Gr.	Ruling Grade	Max. Curvature	Dir. of Traf	Wgt. Hviest Train	Type & Tractive Power Operated	Ventilation
GREAT	LAKES	REGION				NEW YORK	ONTARIO &	WESTERN							
[illegible]	[illegible]	[illegible]			13'8"	[illegible] Brick	[illegible]	[illegible] & Tangent	[illegible]	[illegible]		South	[illegible]	4-8-2 71 850*	Portal
[illegible]	[illegible]	[illegible]				[illegible] Brick	[illegible] NB	Tangent	[illegible]	[illegible]		South	[illegible]	"	"
[illegible]	[illegible]	[illegible]		17'4		[illegible] Brick	[illegible] NB	5°09	[illegible]	[illegible]		South	4400	"	"
[illegible]	[illegible]	[illegible]				Concrete	.23% NB	Tangent & 6°00	Not on	+1.70%		North	3700	2-4-0 43 100#	"
						PITTSBURGH	AND WEST	VIRGINIA							
[illegible]	[illegible] Pa	[illegible]14		22	27'	Concrete	[illegible] WB	Tangent	None	+1.0%	5°00	EW	1530	2-8-0 58.620*	Portal
[illegible]	[illegible] Pa	[illegible]	2	22	27'	"	+1.0% +0.8% WB	"	None	+1.0%	5°00	EW	2745	2-6-6-4 113 500*	"
[illegible]	[illegible] Pa	[illegible]3		22	27'	"	[illegible] WB	"	Not on	+1.0%	5°00'	EW	4800	"	"
[illegible]	[illegible] Pa	[illegible]		22	27'	"	-0.[illegible]% WB	"	Not on	+1.0%	5°00	EW	4800	"	"
[illegible]	[illegible] Pa	[illegible]		22	27'	"	0.[illegible] WB	"	Not on	+1.0%	5°00	EW	4800	"	"
[illegible]	[illegible] Alexandria	[illegible]3		22'	27'	"	+0.7[illegible]% WB	"	Not on	+1.0%	5°00'	EW	2700	2-8-2 65,124*	"
[illegible]	[illegible]	[illegible]25	2	22	27'	"	[illegible]5% WB	"	Not on	+1.0%	5°00'	EW	2700	"	"
[illegible]	[illegible] Pa	[illegible]	1	[illegible]	17	"	+0.35% EB	"	Not on	+1.0%	7°00'	EW	3650	2-6-6-4 113 500	"
[illegible]	[illegible] Pa	[illegible]	1	21-7	16	Timber	+1.0% EB	Tangent & Curve	Not on	+1.0%	15°00'	EW	3650	"	"
						TORONTO	HAMILTON	& BUFFALO							
[illegible]	[illegible]	[illegible]	2			Miscellaneous	[illegible]35% EB	Tangent	Not on	EB 0% WB [illegible]%	6°-30' [illegible]°00	West	6000	Berkshire 81 000*	Portal
							UNION								
[illegible]	[illegible] Bessemer, Pa	[illegible]	2			Brick	[illegible] WB	Tangent & [illegible]	Not on	+1.29% WB	[illegible]°30	N&S	8400	3 (0-10-2) 91.900*	Shaft
[illegible]	[illegible] Pa	[illegible]	2		31'	Concrete	[illegible] WB	Tangent	[illegible]	[illegible] WB	7°00	N&S	8400	"	Portal
CENTRAL	EASTERN	REGION				BALTIMORE	AND	OHIO							
[illegible]	[illegible]	[illegible]	2			Stone & Brick	+1.24% EB	T, 8°00', T		+.30% EB	8°00'	East	[illegible]650	Q-4 63 200*	Portal
[illegible]	[illegible] Md	[illegible]	2	18'		" "	+0.80% EB	[illegible]	None	+0.80% EB	10°-16'	"	3500	Q 4 + Electric Helper	"
[illegible]	[illegible] Md	[illegible]	2	[illegible]		Brick	[illegible] WB	Tangent		+0.25% EB	[illegible]°30	"	8100	Q 4 63 200*	"
[illegible]	[illegible] Md	[illegible]	2	23'		Stone & Brick	[illegible] WB	[illegible] spiral, T		[illegible] EB	[illegible]°30	"	8100	"	"
[illegible]	[illegible] Md	2758	2	[illegible]		" "	[illegible] EB	[illegible] & Tangent		[illegible] EB	[illegible]°30	"	8100	"	"
[illegible]	Orleans Rd W Va	1015	2	24'6"	31'	Concrete & Brick	[illegible]% WB	4°00		[illegible] EB	6°00	"	12000	5-1 84 300*	"
Stuart	" " "	[illegible]	2	24'6		" "	+0.04% WB	2°30' & Tangent		[illegible] EB	6°00	"	12000	"	"
Graham	[illegible]le Cacapon W Va	[illegible]592	2	24'		" "	+0.12% EB	Tangent		+0.25% EB	6°00	"	12000	"	"
[illegible]	McKenzie Md	[illegible]	2	22		Stone & Brick	+0.30% EB	3°00 & Tangent	None	+0.30% EB	11°00	"	4275	Mallet 118 800*	"
Kingwood old	Tunnelton W Va	[illegible]	1	20		" "	+1.00% EB	Spiral, Tangent 1°00'		+[illegible]4% EB	11°00	"	4275	Mallet plus Helpers	"
" new	"	[illegible]	2	24	31'	Stone Conc & Br	+0.40% EB	9°15 & Tangent		+[illegible]% EB	11°00	"	4275	"	"
No 1	Bridgeport W Va	[illegible]710	1	[illegible]		Stone	+0.76% WB	5°45 Tangent 5°45		+.30% EB	8°15'	"	2900	3-3 + Q1c 53 800* + 54,600*	Mech.
No 2	Maken W Va	[illegible]088	1	18'	14	"	+0.95% EB	Tangent		+.30% EB	8°-15'	"	2900	"	Portal
No 6	W Union, W Va	2297	1	[illegible]	14	"	+0.29% EB	Tangent & 5°45		+.30% EB	8°15	"	2900	"	"
No 19	Silver Run, W Va	[illegible]494	1	[illegible]	14'6"	Stone & Brick	+[illegible]00% WB	5°45 Tangent 5°45		+1.30% EB	8°15'	"	2900	"	"
No 21	Eaton W Va	2021	1	16'3"	14'	" "	+0.91% EB	5°30' Tangent 5°30		+1.30% EB	8°15	"	2900	"	Mech
No 2 of Twin	Porters Falls, W Va	[illegible]046	1	18	16	" "	+0.03% WB	Tangent		+0.50% EB	8°50	"	4000	"	Portal
No 3 Summit	Hartzel, W Va	3215	1	18	16'	" "	+0.21% WB	3°00, Tangent, 3°00		+0.50% EB	8°50	"	4000	"	Shaft
Board Tree	Board Tree, W Va	[illegible]400	1	16'6"	11	" "	+0.99% +1.17% +1.04% EB	Tangent & 9°00'		+1.80% WB	10°-10'	West	2250	"	Portal
Welling	Cogley W Va	1301	1	18'6"	22'9"	" "	+0.60% EB	Spiral, Tang, Spiral		+1.80% WB	10°-10'	"	2250	"	"
No 10 Jacksonville	Emmart W Va	[illegible]887	1	21'6"	16'	Stone Conc & Br	+1.23% EB	10°00' & Tangent		+3.00% EB	12°00	East	900	E-24 Double 40 000#	"
No 11 Delta	Braxton W Va	1171	1	22	16	Concrete & Brick	+0.23% EB	Tangent		+3.00% EB	12°00'	"	900	"	"
[illegible]	[illegible], W Va	[illegible]348	1	[illegible]	15'	" "	+0.13%, [illegible] WB	"		-3.00% EB	12°00	"	900	E-24 Double 40,000*	"
[illegible]	[illegible], Ohio	[illegible]	2	23	30'	Stone & Brick	[illegible]%, +0.[illegible]% EB	4°00 & Tangent		+0.97% WB	8°-00'	West	10,000	EL 1a 2a 3a, 5a 118.800*	"
[illegible]	[illegible] Pa	[illegible]	2	24'10"	31	Concrete & Brick	+0.91% +0.51% WB	Tangent		+1.25% EB	8°45'	East	6650	S 1, 84300* + Helper	Shafts
Pinkerton	Pinkerton Pa	[illegible]81	2	23'6"	28'	Stone & Brick	+0.45%, +0.19% EB	4°00', 6°00', 5°00		+1.25% EB	8°45	"	6650	"	Portal
[illegible]	Fort Hill Pa	1866	1	[illegible]	26	" "	+0.10%, +0.50% EB	8°00', Tangent, 6°3[illegible]		+1.[illegible]% EB	8°45'	"	6650	"	"

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TUNNEL	LOCATION	Length	Trks	Hght	Wdth	LINING	THROUGH GRADES	TUNNEL ALIGNMENT	Reduction of Rul.Gr.	Ruling Grade	Max. Curvature	Dir. of Traf.	Wgt. Hviest Trains	Type & Tractive Power Operated	Ventilation
CENTRAL	EASTERN	REGION				BALTIMORE	AND	OHIO							
[illegible]	[illegible] Pa	[illegible]	2	[illegible]	26	Stone & Brick	+0.0 +0.60% +0.8% EB	3°15', 3°00', Tang		+1.7% WB	14°-25'	West	7000	S-1 84,300*	Portal
[illegible]	[illegible] Pa	650	2	23	30'	Brick	+1.41% WB	Tangent		+1.85% EB	12°00'	East	4500	EL-1a, 3a, 5a 118,800	”
[illegible]	[illegible] Pa	[illegible]	2	[illegible]	30	”	+0.38% -0.0% 0.54% W	”		+1.85% EB	12°00	”	4500	”	”
[illegible]	[illegible] Pa	[illegible]	1	[illegible]	[illegible]	Stone & Brick	+1.31% EB	5°45' & Tangent		+1.85% EB	12°00'	”	4500	”	”
[illegible]	[illegible] Pa	[illegible]	1	[illegible]	[illegible]	” ”	+0.0% +0.86% WB	3°-40'		+1.8% EB	12°00	”	4500	”	”
[illegible]	[illegible] Pa	[illegible]	1	[illegible]	[illegible]	” ”	+0.46% EB	Tangent		+1.1% EB	8°-24'	”	3300	E27ca 50,900* E24a, 40,000*	”
[illegible]	[illegible] Pa	[illegible]	2	[illegible]	30	Stone Conc & Br	-0.44% EB	Tangent		+1.34% EB	9°22'	”	6900	K K 80,000*	”
[illegible]	[illegible] Pa	[illegible]	1	[illegible]	[illegible]	Concrete	+[illegible]% -0.48% WB	5°00 Tang 8°00		+2.40% EB	18°-00'	”	2200	E27ca 50,900*	”
[illegible]	[illegible]	[illegible]	1	21'	30'	Brick	+0.5[illegible]% - .22% -0.44% W	2°00 Tang [illegible]°08'		+1.10% EB	9°30'	”	3500	G 3 53,800* E27ca, 50,900*	”
[illegible]	[illegible]	1160	1	[illegible]	18'	Stone & Brick	+0.25% +[illegible]% EB	3°30'		+1.10% EB	9°30'	”	3500	”	”
							PENNSYLVANIA								
[illegible]	[illegible] NYC	5,600	2	[illegible]	[illegible]	Concrete	-1.9% +1.2% NB	Max 1°30		Passenger	Service	E&W	1500	4-6-6-4 (Elec) 72,800*	Mech
[illegible]	[illegible] NYC	[illegible]	[illegible]	[illegible]	[illegible]	”	[illegible] EB	Max 1°30		”	”	E&W	1500	”	Mech
[illegible]	[illegible] Pa	[illegible]	2	17'-6"	30	Brick	[illegible]%	Tangent & 6°00		1.0%	6°00	West	6520	2 (”)	Portal
[illegible]	Baltimore, Md	[illegible]	1	[illegible]	24	Brick & Steel [illegible]	[illegible]%	Tangent		0.99% NB	8°-30	North	4300	2(4-6-4 (Elec)) 56,250*	”
[illegible]	Baltimore, Md	3333	2	22'3	[illegible]	[illegible] & C Rings	[illegible]%	Tangent		0.99% NB	8°-30	”	4300	”	”
B & P	Baltimore Md	6994	2	[illegible]	[illegible]	Brick	1.34%	Tangent & 7°30		0.99% NB	8°-30'	”	4300	”	Mech.
[illegible]	Washington DC	[illegible]	1	[illegible]	[illegible]	Concrete	0.[illegible]%	Tangent & [illegible]	Not on	0.99% NB	8°30'	”	4300	”	Portal
[illegible] EB	Washington DC	[illegible]	1	[illegible]	16	Brick	[illegible]%	Tangent & 4°[illegible]	”	0.99% NB	9°30	”	4300	”	Mech.
[illegible] NB	Washington DC	[illegible]	1	[illegible]	[illegible]	”	0.[illegible]%	Tangent & 4°20	”	0.99% NB	8°30'	”	4300	”	Mech
[illegible]	Spruce Creek Pa	[illegible]	1	[illegible]	28	[illegible]	[illegible]%	Tangent	”	0.3% EB	6°45'	West	9800	4-8-2 64,500*	Portal
[illegible] NB	Spruce Creek Pa	[illegible]	2	20'	28	[illegible]	[illegible]	Tangent	”	0.3% EB	6°-45	”	9800	”	”
[illegible]	Gallitzin Pa	[illegible]	1	[illegible]	[illegible]	[illegible]	1.0%	Tangent		.85% NB	9°25	”	5200	4 - I1sa 96,026* each	Mech.
[illegible]	Gallitzin Pa	3595	1	[illegible]	24	Brick	[illegible]%	Tangent		.85% WB	9°25	”	3900	3 I1sa 96,026* each	Portal
New Portage	Gallitzin Pa	1629	2	[illegible]	[illegible]	Concrete	.34%	Tangent	”	.44% EB	7°-47'	East	7200	I1sa 96,026*	”
[illegible]	[illegible] Pa	[illegible]	2	[illegible]	25'	Brick & Rock	0.30%	6°00' & Tangent		[illegible]% WB 0.30% EB	13°00	”	6600	I1sa + I1s 96,026* + 90,024*	”
East Brady	East Brady Pa	2462	[illegible]	21'2	30	Conc & Brick	[illegible]%	5°00		0.50% NB 0.30% SB	7°-00'	North	7000	”	”
[illegible]	[illegible] Pa	[illegible]	1	[illegible]	30	” ”	0.[illegible]%	[illegible] & Tangent		0.50% NB 0.30% SB	7°00	”	7000	”	”
[illegible]	[illegible] Pa	[illegible]	1	21'-6"	[illegible]	”	[illegible]%	[illegible] & Tangent		0.50% NB 0.30% SB	7°00'	”	7000	”	”
[illegible]	[illegible] Pa	696	1	[illegible]	23'-9"	” ”	0.15%	Tangent	50%	[illegible]% NB 0.30% EB	[illegible]°00	East	6780	L-1s 61,465*	”
[illegible]	[illegible] Pa	[illegible]	2	[illegible]	[illegible]	Unlined	0.57%	8°00 & 4°00		1.0%	9°00	E&W	1440	M-1a 64,500*	”
[illegible]	[illegible] Pa	2370	[illegible]	[illegible]	[illegible]	Brick	0.61%, 0.79%	Tangent & 4°45		1.0%	9°00	”	1440	”	”
[illegible]	[illegible]	3320	[illegible]	21'-8"	[illegible]	”	0.71%	Tangent		1.0%	10°00'	”	4400	I-1s 90,024*	Mech
[illegible]	[illegible] Ohio	[illegible]	2	[illegible]	[illegible]	”	0.75%	”		1.0%	10°00'	”	4400	”	Portal
Cadiz Jct	Cadiz Jct Ohio	1331	2	[illegible]	[illegible]	”	0.67%	”		1.0%	10°00'	”	4400	”	”
[illegible]	[illegible] Ohio	1420	[illegible]	[illegible]	24'-7"	”	0.53%	”		1.0%	10°-00'	”	4400	”	”
[illegible]	[illegible] W Va	1226	2	[illegible]	26	Miscellaneous	0.86%	”		0.86%	10°-00'	”	2000	L-1s 61,465*	”
[illegible]	[illegible] W Va	[illegible]	2	[illegible]	[illegible]	Brick	0.39%	”		0.86%	10°-00	”	2000	”	”
[illegible]	[illegible] Ohio	[illegible]	1	[illegible]	14'[illegible]	Unlined	1.14%, 0.[illegible]%	”		1.0%	6°00'	”	3500	H-10 53,197*	”
[illegible] City	[illegible] City Ohio	[illegible]	1	17'10"	18'-7"	”	0.60%	Tangent & [illegible]°47'		0.75% SB 0.80% NB	13°-14'	North	5000	I1s 90,024*	”
[illegible] #2	Cincinnati Ohio	1046	2	[illegible]	26	Brick	1.13%	Tangent & 9°00'		1.62% WB	10°-40'	West	700	4 10s (2-8-0) 53,197*	”
						READING		COMPANY							
Mahanoy	Mahanoy [illegible] Pa	[illegible]	1	[illegible]	13'	Stone Conc & Timb	+0.6% NB	Tangent	Not on	+1.7% SB	11°-00'	South	4900	Mallet 111,400*	Mech
[illegible]	[illegible] Pa	[illegible]	2	17'	23'	Brick Conc & Stone	+1.15% NB	Tangent & 3°30'	”	+1.28% NB	3°30'	N & S	1600 1650	Mikado 60,800* Consol 64,300	Shaft
[illegible]	Phoenixville Pa	1932	2	16'-[illegible]	[illegible]	Stone & Conc	+0.[illegible] NB	Tangent	”		8°00'	South	10,000	Consolidated 71,000*	Shafts
[illegible]	Dillinger, Pa	[illegible]	1	16'6	13'6	Conc Brick & Timb	+0.14% -0.14% NB	Tangent	”	+1.05% NB	8°30'	”	3400	Consolidated 64,300*	Portal
[illegible]	[illegible] Pa	[illegible]	1	16'[illegible]	13'	Br Conc & Timber	+0.4[illegible]% SB	Tangent & 11°24'	”	+0.81% SB	12°30	”	6250	”	”

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Tunnel	Location	Length	Trks	Hght.	Width	Lining	Through Tunnel Grades	Through Tunnel Alignment	Reduction of Rul. Gr.	Ruling Grade	Max. Curvature	Dir. of Traf	Lgt. Hviest Trains	Type & Tractive Power Operated	Ventilation
CENTRAL	[illegible]	REGION				CENTRAL	R R OF	NEW JERSEY							
[illegible]	[illegible]	[illegible]		18	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
						WESTERN		MARYLAND							
[illegible]	[illegible]	[illegible]	1	[illegible]	17'	[illegible]	[illegible]	Tangent	[illegible]	[illegible]	[illegible]	East	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	1	[illegible]			[illegible]		"	[illegible]	[illegible]	"	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	17'		[illegible]	[illegible]	"	[illegible]	6°14'	"	[illegible]		"
[illegible]	[illegible]	[illegible]	1	[illegible]		"	[illegible]	[illegible]		[illegible]	6°14'	"	[illegible]	"	"
[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	"	[illegible]	"	"
[illegible]	[illegible]	[illegible]	1	[illegible]	13'8"	[illegible]	[illegible] EB	[illegible]	[illegible]	[illegible]	16°00'		3200	[illegible]	"
[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		"
						WHEELING	& LAKE	ERIE							
[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Portal
POCAHONTAS	REGION					CHESAPEAKE	AND	OHIO							
[illegible]	[illegible]	[illegible]			18'	[illegible]	[illegible]	[illegible]		[illegible]	10°28'	[illegible]	[illegible]	[illegible]	Portal
[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	10°28'	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Mech.
[illegible]	[illegible]				18'	[illegible]	[illegible]	[illegible]		[illegible]		[illegible]	[illegible]		Portal
[illegible]	[illegible]	[illegible]				Brick & Conc.	[illegible]	[illegible]			[illegible]		[illegible]		
[illegible]	[illegible]	[illegible]		22'11"	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]		[illegible]	[illegible]	[illegible]	"
[illegible]	[illegible]	2067		[illegible]	[illegible]	"	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	"
[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	"
Big Bend	[illegible]	6168	1		18'		[illegible]	Tangent		[illegible]	6°00'	[illegible]	11,900	[illegible]	"
[illegible]	[illegible]	[illegible]			[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	"
[illegible]	[illegible]	[illegible]	1	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]		"
[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	15°00'	[illegible]	8000	2-8-8-2 [illegible]	"
[illegible]	[illegible]	[illegible]	1	18'5"	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]		"
[illegible]	[illegible]	1472	[illegible]			"	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	"
						NORFOLK	AND	WESTERN							
[illegible]	[illegible]	[illegible]	1		15'	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Mech.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]		1% EB	[illegible]	"	[illegible]	"	Portal
[illegible]	[illegible]	[illegible]	[illegible]	18'	14'	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	"	[illegible]	[illegible]	Mech.
[illegible]	[illegible]	[illegible]	[illegible]	23'6"	28'	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]		Portal
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	"	[illegible]	"		[illegible]	12°30'	[illegible]	[illegible]	[illegible]	"
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]			[illegible]	[illegible]	"	[illegible]	"	"
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	28'	"	[illegible]	"		[illegible]	12°30'	"	[illegible]	"	"
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	"	[illegible]	[illegible]		[illegible]	[illegible]	"	[illegible]	[illegible]	"
[illegible]	[illegible]	[illegible]		20'	[illegible]	"	[illegible]	[illegible]		[illegible]	8°00'	[illegible]	[illegible]		"
[illegible]	[illegible]	[illegible]		20'			[illegible]	[illegible]		[illegible]	8°00'	[illegible]	[illegible]		"
[illegible]	[illegible]	[illegible]	1	[illegible]	17'	"	[illegible]	"		[illegible]	8°00'		[illegible]		"
[illegible]	[illegible]	1800			[illegible]		[illegible]	[illegible]		[illegible]	8°00'	[illegible]	[illegible]		"
[illegible]	[illegible]	[illegible]	1		18'	"	[illegible]	[illegible]	"	[illegible]	[illegible]	[illegible]	[illegible]		
[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	Tangent	[illegible]	[illegible]	16°00	[illegible]	2000	[illegible]	"
Big Bull	[illegible]	1661	1	[illegible]	14'	[illegible]	-1.6% EB	"	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	"
[illegible]	[illegible]	[illegible]		[illegible]	14'	[illegible]	[illegible]			[illegible]	[illegible]		[illegible]		"
[illegible]	[illegible]	1933	[illegible]	[illegible]	[illegible]	" "	[illegible]		[illegible]	[illegible]	16°00		[illegible]	"	"
[illegible]	[illegible]	4773	1	23	16'	Concrete	[illegible]	"		[illegible]	12°00	[illegible]	[illegible]	[illegible]	"
[illegible]	[illegible]	[illegible]	1	[illegible]	[illegible]	"	[illegible]			[illegible]	12°00	[illegible]	[illegible]	"	"
[illegible]	[illegible]	[illegible]	1	[illegible]		"	[illegible]	"		[illegible]	[illegible]	[illegible]	[illegible]	" SHEET 4	"

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							GRADES	ALIGNMENT							
[illegible]	POCAHONTAS	REGION				NORFOLK	AND	WESTERN							
[illegible]	[illegible] Creek Ky	[illegible]	1	20.8	17	Concrete	+0.3% NB	Tang & Spiral	Not on	1.72%	10°30	North	2250	Y 3 114,200*	Portal
							VIRGINIAN								
[illegible]	[illegible], Va	[illegible]	1				+1.22% WB	Tangent		0.6% EB	9°30	East	9000	Electric 231,000*	Portal
[illegible]	[illegible] Gap, W.Va	1966	1				+0.58% WB	"		0.6% EB	9°30'	"	9000	"	"
[illegible]	[illegible] Gap, W.Va	1699	1				+1.27% WB	"		0.6% EB	9°30'	"	9000	"	"
[illegible]	[illegible] W.Va	[illegible]	2				+1.80% EB	"	0.27%	2.07% EB	12°12'	"	6000	"	"
[illegible]	[illegible] W.Va	[illegible]	2				+1.88% EB	"	0.19%	2.07% EB	12°12'	"	6000	"	"
[illegible]	[illegible] Gap, W.Va	2463	1				+0.80% EB	Tangent & 8°00	0.20%	+1.0% EB	12°00	"	3500	2-8-8-2 101,300*	"
[illegible]	[illegible] W.Va	[illegible]	1				+0.27% EB	3°30		0.69% EB	12°00'	West	15000	2-10-10-2 147,200*	"
[illegible]	[illegible] W.Va	[illegible]	1				+0.57% EB	3°00'		0.69% EB	12°00	"	15000	"	"
[illegible]	[illegible] W.Va	[illegible]	1				+0.57%	4°00		0.69% EB	12°00	"	15000	"	"
[illegible]	Justice W.Va	[illegible]	1				+0.50%	4°00		[illegible] EB	12°00'	"	15000	"	"
	SOUTHERN	REGION				CENTRAL	OF	GEORGIA							
[illegible]	[illegible], Ga	[illegible]	1	[illegible]	16.2'	Partly Brick	+0.82% -0.37% NB	Tangent	Not on	+1.33% EB	7°55'	East	1800'	2-10-2 73,800*	Portal
[illegible]	[illegible], Ga	[illegible]	1	[illegible]	[illegible]	" "	+[illegible]% NB	Tangent & 6°00	"	+0.50% E	8°50'	"	3700	"	"
							CLINCHFIELD								
[illegible]	[illegible], Va	[illegible]				Unlined	+.35% +1.19% SB	Tangent & 4°00	none	+1.0% SB	4°00	South		2-8-8-2	Portal
[illegible]	[illegible] Va	[illegible]	1	[illegible]	18	Concrete	+0.36% SB	6°00	Not on	+1.0% SB	4°00	"		"	"
[illegible]	[illegible] Va	1359	[illegible]	[illegible]	8'	"	+0.79% SB	Tangent	Not on	+[illegible] SB	14°00	"		"	"
[illegible]	[illegible] Va	[illegible]	1	21'	18'	"	+0.50% SB	Tangent	50%	+1.0% SB	14°00	"	7200	"	"
[illegible]	[illegible] Va	[illegible]	1	21'	8'	"	0.20% SB	"	Not on	+1.0% SB	14°00	"	7200	"	"
[illegible] Ferry	Speer Ferry Va	[illegible]	1			Unlined	+0.28%, +0.06% S	Tangent & 6°00	"	+1.0% SB	14°00	"	7200	"	"
[illegible]	Speers Ferry Va	[illegible]	1	21'	8	Concrete	[illegible]	Tangent	"	+1.0% SB	14°00	"	7200	"	"
[illegible]	[illegible] Tenn	[illegible]	1	21'	18'	Partly Concrete	+0.33% SB	2°00	"	+[illegible] SB	14°00	"	7200	"	"
[illegible]	[illegible]	[illegible]	1	21'	18	" "	-0.70% SB	Tangent	"	+1.4% SB	14°00'	"	7200	"	"
[illegible]	[illegible] N.C	[illegible]	1	21'	18	" "	1.19% SB	"	"	+1.4% SB	14°00	"	7200	"	"
[illegible]	[illegible] N.C	6.8	1			Unlined	- .20% SB	"	"	+1.4% SB	4°00	"	7200	"	"
[illegible]	[illegible] N.C	2211	1	21'	18'	Partly Concrete	1.20% SB	"	"	+1.4% SB	4°00	"	7200	"	"
[illegible]	[illegible]	[illegible]	1	21'	18'	" "	-0.88% -1.20% SB	8°00' & Tangent	"	+1.4% SB	14°00	"	7200	"	"
[illegible]	[illegible] N.C	[illegible]	1	[illegible]	18'	Concrete	+0.40% SB	2°18'	"	+1.4% SB	14°00'	"	7200	"	"
						ILLINOIS		CENTRAL							
[illegible]	[illegible] Wis	1217	1	18'6"	[illegible]	[illegible] & Timb	+0.15% Level 0.25% NB	2°00	Not on	+0.76% NB +1.00% SB	4°00	North	1400	2-8-0 33,699*	Portal
[illegible] #2	[illegible] Ill	[illegible]	1	23'3"	18'	Concrete	Level	Tangent & 1°30	"	0.30% NB SB	1°30'	"	6300	2-8-2 65,870*	"
[illegible] #3	[illegible], Ill	[illegible]	1	[illegible]	[illegible]	Concrete	-0.21% [illegible]	Tangent	"	+0.30% NB SB	1°30'	"	6300	"	"
						LOUISVILLE	AND	NASHVILLE							
Diana	[illegible] Tenn	[illegible]	1	[illegible]	[illegible]	Concrete	+0.16% SB	Tangent & 2°30		NB +0.50% SB +0.40%	4°04	N&S	3300	Mikado 63,000*	Portal
Blount Springs	Blount Springs Ala	[illegible]	2	24	31'	Unlined	+[illegible]% NB	Tangent & 4°00		SB +0.42% NB +1.07%	6°00	"	3250	"	"
[illegible]	[illegible] Ala	[illegible]	2	24.8	[illegible]	Concrete	+0.40% SB	Tangent & 4°00		NB +0.50% SB	6°00	"	3250	"	"
Brock's Gap	[illegible] Ala	[illegible]	2	29	21'3"	"	+0.62% SB	Tangent		SB +0.92% NB +1.07%	6°00	"	3000	"	"
Lester	[illegible] Tenn	[illegible]	1	[illegible]	14.4	Unlined	+1.25% SB	Tang, 3°00, 3°30'		SB +1.30% NB +1.40%	4°06	"	1025	Consolidation 39,300*	"
[illegible] Gap	[illegible] Gap, Ala	1899	1	[illegible]	14.3	Partly Timber	-0.53% SB	Tangent & 8°00		SB +1.20% NB +1.25%	8°00'	South	1950	Mikado 63,000*	"
Muldraughs	[illegible]ington, Ky	[illegible]	1	[illegible]	12.6"	Unlined	+1.70% SB	Tangent & 6°00		SB +1.7% NB +1.73%	8°00'	North	500	Consolidation 28,200*	"
Eastwood	Eastwood Ky	1626	1	[illegible]	16'	Concrete	+1.01%, 0.96% SB	Tangent		SB +1.09% NB +1.27%	4°00	South	2100	Mikado 63,000*	"
Pleasant Vly	Pleasant Valley, Ky	1132	1	20'	16.9"	Concrete	+1.42% NB	Tangent		SB +2.10% NB +1.33%	8°00	"	800	Consolidation 31,900*	"
Bakers Hill	Ridgetop Tenn	4616	1	[illegible]	18'	Unlined	+0.[illegible]% NB	Tangent	0.20%	SB +0.80% NB +0.90%	6°54'	"	3400	Mikado 63,000*	"
Chenowee	Chenowee, Ky	[illegible]	1	20	16.1'	"	+0.40% NB	Tangent & 8°30		NB +0.20%	12°00'	North	6180	"	"
Dumont	Dumont, Ky	1013	1	20'4"	16'6"	Partly Conc	Level	8°00		NB +0.20%	12°00'	"	6180	"	"
[illegible]	[illegible]wick, Ky	[illegible]	1	20'2"	17'1"	Concrete	+0.10% NB	4°00 & 8°00		NB +0.21%	12°00'	"	6180	"	"

SHEET 5

TUNNEL
continued
Hazard
Torrent
Cumberland G
Tazewell
Carwood
Redwine Ga
Hagans
Grant
Cove Cree
Vasper
Dossett
Copper Ridge
Cumberland M
Chattanooga
Hardwick
Rivermont
Swannanoa
Indian Gra
Elk Gap
Duncan
Burton
No. 2
No. 3
No. 4
No 7
No 9
No 15
No 16
No 24
No 26
Lookout Mt
Tunnel Cit
Pipestone Pa
Blacktail, *
Garrison
Nimrod
St Paul Pas
Moss Creek
Sage Creek
Watts
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Horlick *2
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TUNN.	LOCATION	Length	Tracks	Height	Width	LINING	THROUGH GRADES	TUNNEL ALIGNMENT	Reduction of Rul. Gr.	Ruling Grade	Max. Curvature	Dir. of Traf.	Wt. Heaviest Trains	Type & Tractive Power Operated	Ventilation
[illegible]	SOUTHERN	REGION				LOUISVILLE	AND	NASHVILLE							
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Concrete	[illegible]	Tangent & 6°00		[illegible] NB	1[illegible]°00	North	6180	Mikado 63,000*	Portal
[illegible]	[illegible]	[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible] SB	Tangent & 6°30		[illegible]	10°00	"	720	Consolidation 2[illegible],700*	"
[illegible]	[illegible]	[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible] SB	Tangent		[illegible] SB [illegible] NB	10°00	NB[illegible]	1190	Consolidation 49,000*	"
[illegible]	[illegible]	[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible] SB	Tangent & 10°00		[illegible] SB +.48% NB	10°00	"	1190	"	"
[illegible]	[illegible]	[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible] SB	Tangent & 6°[illegible]		[illegible] SB [illegible] NB	10°00	South	3300	Mikado 63,000*	"
[illegible]	[illegible]	[illegible]	1	[illegible]	[illegible]	Concrete	[illegible] SB	Tangent		[illegible] SB [illegible] NB	10°00	"	3300	"	"
[illegible]	[illegible]	[illegible]	1	[illegible]	[illegible]	"	+0.[illegible] SB	Tangent		[illegible] B +0.[illegible] NB	10°00	"	3300	"	"
[illegible]	[illegible]	[illegible]	1	[illegible]	[illegible]	"	+0.[illegible] B	Tangent & 6°30		[illegible] B +0.2[illegible] NB	1[illegible]°30	North	2[illegible]0	"	"
[illegible]	[illegible]	[illegible]	1	[illegible]	[illegible]	[illegible] Concrete	+0.37% SB	Tangent & 6°00		[illegible] B +[illegible]% NB	10°00	South	3015	"	"
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Brick	0.48% SB	Tangent & 6°00		[illegible] SB +0% NB	10°00	"	3015	"	"
[illegible]	[illegible]	[illegible]	1	[illegible]	[illegible]	[illegible] Conc	+0.4[illegible] B	Tangent		[illegible] B [illegible] NB	10°00	"	3015	"	"
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Concrete	[illegible] SB	Tangent		[illegible] B +1.0% NB	[illegible]	"	2075	"	"
						NASHVILLE	CHATTANOOGA	& ST. LOUIS							
[illegible]	[illegible] Tenn	[illegible]	1	[illegible]	16'4"	Unlined	+0.32% & 0.42% SB	Tangent		+.8%	6°22'	South	2200	Mikado 65,800*	Shafts
[illegible]	[illegible] Ga	5[illegible]	1	22	16	Concrete	-0.73% SB	"	[illegible]	+0.81%	6°00	"	2650	"	Portal
						SEABOARD	AIR	LINE							
[illegible]	[illegible] Ala	370	1	21	17'	Concrete	-0.30% WB	Tangent & 6°00	0.3%	+1.0%	9°00'	E&W	2000	Santa Fe 69,400*	Portal
							SOUTHERN								
[illegible]	[illegible] Va	[illegible]	2	[illegible]	[illegible]	Concrete	[illegible] B	3°[illegible] & Tangent	[illegible]	[illegible] NB [illegible] SB	[illegible]°00	North	2900	Mikado 59,850*	Portal
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] Brick	[illegible] NB	Tangent	[illegible]	[illegible] EB [illegible] NB	2°00	E[illegible]	1450	Santa Fe 71,[illegible]00*	"
[illegible]	[illegible] Tenn	[illegible]	[illegible]	[illegible]	[illegible]	Brick & Stone	[illegible] NB	Tangent	[illegible]	+1.80% [illegible] +1.80% NB	[illegible]°00		1320	Consolidation 4[illegible]00*	"
[illegible]	[illegible] Tenn	[illegible]	1	[illegible]	[illegible]	Brick	[illegible] SB	6°30 & Tangent		[illegible] EB [illegible] NB	10°00		925	"	"
[illegible]	[illegible]	[illegible]	1	[illegible]	4	Unlined	[illegible] NB	4°00 & Tangent		[illegible]0% EB [illegible]0% NB	7°00		1250	Consolidation 46,[illegible]00*	Shafts
[illegible]	[illegible]	[illegible]	1	[illegible]	16	Concrete	[illegible] 0.22% WB	[illegible] & Tangent		[illegible] EB [illegible]0.93% NB	6°00		2600	Mikado 53,900*	Portal
No 2	[illegible] Ky	[illegible]		[illegible]	[illegible]	Brick & Stone	[illegible] SB	Tangent		[illegible] NB [illegible]	[illegible]°[illegible]0	North	2000	Mikado 59,850*	Shafts
No 3	Burnside Ky	[illegible]	1	[illegible]	18.5'	Unlined	+1.12% NB	6°00 & Tangent		[illegible] NB [illegible] SB	[illegible]°[illegible]0		2000	"	Portal
No 4	Burnside Ky	1165	1	[illegible]	9	"	[illegible] NB	4°00 & Tangent		[illegible] B [illegible]20% B	[illegible]°10	"	2000	"	"
No 7	Greenwood, Ky	1160	1	[illegible]	5	Brick & Stone	[illegible]% B	6°00 & Tangent	"	[illegible] +1.2[illegible]% SB	6°10	"	2000	"	"
No 9	Greenwood Ky	276	1	[illegible]	15	"	[illegible] B	6°00 & Tangent	"	[illegible] NB +.20% SB	6°10	"	2000	"	"
No 15	[illegible], Tenn	[illegible]	1	[illegible]	[illegible]	Brick	[illegible] B	6°00 & Tangent	"	+1.18% NB +1.20% SB	6°10	"	1550	"	Shaft
No 16	Huffman Tenn	[illegible]	1	[illegible]	[illegible]	Brick & Stone	+0.70% NB	Tangent		[illegible] NB [illegible] B	6°10		1550	"	Portal
No 24	Nemo Tenn	2031	1	[illegible]	[illegible]	" "	[illegible] NB	[illegible]°00	"	[illegible] +1.20% SB	6°10	"	1550	"	"
No 26	[illegible]dale Tenn	[illegible]	1	[illegible]	[illegible]	Brick	+0.61% [illegible] 0.77% [illegible]	6°00 & Tangent		[illegible] NB [illegible]	6°10	"	1550	"	"
[illegible] #1	Chattanooga Tenn	[illegible]	2	[illegible]	[illegible]	Unlined	[illegible] B	3°00 & Tangent		+1.8% NB [illegible] SB	[illegible]°51	"	2600	"	Shaft
	NORTHWESTERN REGION					CHICAGO, MILWAUKEE	ST PAUL & PACIFIC								
[illegible] City	[illegible]	1330	1	[illegible]	14.9	Brick	-0.51% WB	Tangent	Summit	+0.5% EB NB	3°00'	East	4500	4-8-4 70,816*	Portal
[illegible]	[illegible] Mont	2290	1	[illegible]	[illegible]	Concrete	1.0% WB	"	Near Summit	+1.66% EB +2.0% WB	[illegible]°00	"	6000	Electric EF2	"
[illegible] #1	[illegible] Mont	[illegible]	1	[illegible]	18.5	"	-1.6[illegible]% WB	"	None	+1.66% EB +2.0% WB	10°00	"	6000	"	"
[illegible]	[illegible] Mont	2015	1	20'2"	[illegible]	"	-0.4[illegible]% WB	W [illegible] 3°00'	None	+0.42% EB +0.20% WB	4°02'	"	6000	"	"
[illegible]	[illegible] Mont	[illegible]	1	20'[illegible]	[illegible]'11"	"	-0.31% WB	Tangent		+[illegible]% EB +0.20% WB	4°02	"	6000	"	"
St Paul [illegible]	E Portal Mont	8774	1	20'2"	18'1"	"	+1.7%, 0.2% WB	"	Summit	+1.7% EB WB	10°00	"	6000	"	"
[illegible] Creek	Roland, Idaho	[illegible]	1	20'9"	[illegible]	Partly Concrete	1.10% WB	"	None	+1.7% EB WB	10°00	"	6000	"	"
[illegible] Creek	[illegible] Mont	2014	1	21'	16.6"	Concrete	+0.50% WB	"		+1.5[illegible]% EB +1.0% WB	8°00'	"	1250	2-8-2	"
Wolf[illegible]	Sorrento, Wash	[illegible]	1	20'11"	16	"	-0.40% WB	"	None	[illegible]% EB [illegible] B	10°00'	"	5543	2-6-6-2 82,720*	"
Johnson Cr	Boylston Wash	1973	1	21'1"	[illegible]'11"	Partly Conc & Timb	Vertical Curve	6° 00	Summit	+1.6% EB +2.2% WB	8°00'	"	4100	Electric EF2	"
[illegible] #7	[illegible], Wash	1239	1	21'7"	17'8"	Concrete	+0.5% WB	[illegible]° 00		+[illegible] EB [illegible] WB	9°00	"	4100	"	"
Snoqualmie	Hyak Wash	11,890	1	20'1"	[illegible]'11"	"	0.4[illegible]% WB	6°, Tangent, 3°	Summit	+1.74% EB +0.1[illegible]% WB	10°00	"	4100	"	"
[illegible]	Blue Slide Wash	1093	1	22'1"	[illegible]'11"	Conc & Timber	0.10% WB	Tangent		+1.0% EB WB	12°00	"	2815	2-6-6-2 82720*	"

TUNNEL

continuec

Winston

No.2
No 6
No 13
No 14
Cascade
Everett
Seattle
No 18
No 1A
No Q-1
No Q-2
No Q-3
No Q-4
No Q-5
Boulder
No 10
No. 7

St Paul
Duluth

Bozeman
Mullan
Garrison
Quinns
Stampede
Nelson Bennett
Ostrander
Big Horn

Cape Horn
No 16
No 17
Ft Wright
Cornelius
Tophill
CENTRAL
Raton
No 1
No 3
No 4

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TUNNEL	LOCATION	Length	Tks	Hght	Width	LINING	THROUGH TUNNEL GRADES	THROUGH TUNNEL ALIGNMENT	Reduction of Rul.Gr.	Ruling Grade	Max. Curvature	Dir. of Traf	Wgt. Hviest Trains	Type & Tractive Power Operated	Ventilation
	NORTHWESTERN REGION					CHICAGO	GREAT	WESTERN							
[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible] & [illegible]	[illegible] 0.95% EB	Tangent & 3° [illegible]	[illegible]	+1.0% WB +[illegible]% EB	9°30	E&W	3200	Texas 84,600*	Mech
						GREAT		NORTHERN							
No. [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3° Tangent [illegible]		[illegible] EB	10°30	East	5000	R-2 46,000*	Portal
No. [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	"	[illegible]	Tangent		[illegible]	[illegible] 30	"	5400	O-8 78,000*	"
No. [illegible]	[illegible]	[illegible]		[illegible]	16'	"	[illegible] WB	"		[illegible] EB	10°00'	"	5250	Electric 60,000*	"
[illegible]	[illegible]	[illegible]		[illegible]	16'	"	[illegible]	"		[illegible] EB	10°00	"	5250	"	"
[illegible]	[illegible]	[illegible]	1	[illegible]	16'	"	[illegible]	"		[illegible] EB	10°00	"	5250	"	"
[illegible]	[illegible]	[illegible]	1	[illegible]	[illegible]	"	[illegible]			[illegible] WB	10°00	West	5000	R-1 143,500*	"
[illegible]	[illegible]	[illegible]	2	[illegible]	[illegible]		[illegible]	[illegible] Tang		[illegible]	8°00	E&W	3200	O-4 63,800*	"
No. [illegible]	[illegible]	[illegible]	1	[illegible]	[illegible]		[illegible]	Tangent		[illegible]	10°	South	3200	C-5 50,600*	"
No. [illegible]	[illegible]	[illegible]		[illegible]	[illegible]	Timber	[illegible]	[illegible]		[illegible]	3°00	E&W	1000	F-8 41,540*	"
[illegible]	[illegible]	[illegible]	1	21'	17	[illegible] Timber	[illegible] WB	[illegible] Tangent		+0.6% [illegible]	8°20	"	2600	O-6 67,700*	"
No. [illegible]	[illegible]	[illegible]	1	22	[illegible]	Concrete	[illegible] EB	2°[illegible]		+0.[illegible]% EB WB	8°20'	"	2600	"	"
No. G-3	[illegible]	[illegible]	1	22	16	"	[illegible]	Tangent		+0.6% EB WB	8°20	"	2600	"	"
No. G-4	[illegible]	[illegible]	1	22	[illegible]		[illegible]	[illegible] Tangent		+0.6% EB WB	8°20	"	2600	"	"
No. G-5	[illegible]	[illegible]	1	22	[illegible]		[illegible] WB	Tangent		+0.6% WB	8°20	West	2600	"	"
[illegible]	[illegible]	[illegible]	1	17.8	[illegible]	Rock & Concrete	[illegible] WB	"		[illegible] EB	10°00'	East	950	M-2 95,500*	"
No. [illegible]	[illegible]	[illegible]	1	22	[illegible]	Concrete	+2.[illegible] EB	"		[illegible] EB	10°00	"	950	"	"
No. 7	[illegible] Wash	[illegible]76	1	[illegible]	[illegible]	[illegible] Timber	[illegible] WB			[illegible] EB	10°00	"	1000	E-12 22,760*	"
						MINNEAPOLIS	ST PAUL &	S S MARIE							
St Paul	St [illegible] Minn	1218	2	29	32	Concrete	[illegible] EB	Tangent & 3°00		Switch	Service		Only		Portal
Duluth	Duluth "	[illegible]	1	20	16	"	[illegible]	Tangent & 6° [illegible]		"	"		"		"
						NORTHERN		PACIFIC							
Bozeman	[illegible] Mont	[illegible]		20	16	Concrete & Brick	[illegible] WB	Tangent		0.4%		East	4000	4-6-6-4 104,500* + Helper	Portal
Mullan	[illegible] "	[illegible]	1	20	16'	"	[illegible] WB	"		0.4%		"	4000	"	Mech
Garrison	Garrison "	1394	2	24'	28'	Concrete	-0.39% -0.35% 0.40% WB	"		0.4%		"	4000	4-6-6-4 104,500*	Portal
[illegible]	[illegible] "	1120	1	[illegible]6	[illegible]	"	0.6% WB	3°00'		0.5%		"	4000	2-8-2 63,460*	"
Stampede	[illegible] Wash	[illegible]	1	[illegible]	16	[illegible] & Brick	[illegible] 0.78% WB	Tangent		[illegible]		"	2500	2-8-8-2 89,500* + Helper	Mech
Nelson Bennett	Tacoma "	4791	2	24'	28	Concrete	[illegible] [illegible] WB	[illegible]		1%		"	1975	2-8-2 63,460*	Portal
[illegible]	[illegible]	1165	2	[illegible]4	28	"	[illegible] WB Level	Tangent		[illegible]		"	1975	"	"
[illegible]	[illegible] Mont	[illegible]	1	20'	16'	"	[illegible] 0.1% Level			0.5% WB 0.2% EB		"	4500W 6000E	"	"
						SPOKANE	PORTLAND	& SEATTLE							
Cape Horn	Cape Horn, Wash	2360	1	22'	16'	Generally Unlined	Level	3°00 Spiral, Tang		[illegible] EB	3°00'	East	5000	4-6-6-4 104,500*	Portal
No. 6	Fairhaven "	2493	1	22	16	Concrete	+0.3% EB	Tangent		[illegible] EB +0.83% EB	V2 NP 3° V2 GN 8°	"	7200	"	"
No. [illegible]	Kamiacus "	2220	1	22'	16	"	+0.3% EB	"		+1.0% EB +0.83% EB	V2 NP 3° V2 GN 8°	"	7200	"	"
Ft Wright	Spokane "	2124	1	22'	16	"	-1.0% EB	3°00 Spiral, Tang		+1.0% EB +0.83% EB	V2 NP 3° V2 GN 8°	"	7200	"	"
Cornelius	Rockton, Ore	4111	1	22	16	Conc & Timber	+0.2%, -0.2% WB	4°00 Spiral, Tang		+1.5% EB	14°00	"	600	2-8-0 39,200*	"
Tophill	Tophill, "	1136	1	22'	16	Timber	+1.0%, 0.91% WB	8°00 Tang 8°00		+1.5% EB	14°00'	"	600	"	"
CENTRAL	WESTERN	REGION				ATCHISON	TOPEKA &	SANTA FE							
Raton	Wootton Colo Lynn NM	[illegible] [illegible]	1 1	19' [illegible] [illegible]	[illegible] 16-6	Partly Timb & Conc Concrete	[illegible] -1.5% EB +0.52% WB	Tangent & 4°00 Tangent		[illegible] +0.3%	11°00'	East	3000	2-10-2 81,500* + 2-10-2, 74,800*	Portal Shafts
No. 1	[illegible] Hill Calif	[illegible]	1	20	[illegible]	Concrete	[illegible] WB	Tangent		+1.06% WB +1.0% EB	6°00	E&W	2600	Pacific + Helper 39,650* + [illegible]	Portal
No. [illegible]	[illegible] Frazer "	[illegible]	1	[illegible]	[illegible]	"	+0.8%, 0.7% WB	"		+1.06% WB +1.0% EB	6°00	"	2600	"	"
No. 4	[illegible] "	1045	1	20'1"	[illegible]	Timber	-0.16% WB	1°20'		+1.06% WB +1.0% EB	6°00	"	2600	"	"
						CHICAGO	BURLINGTON	& QUINCY							
No. 1	Guernsey Wyo	3334	1	21'[illegible]	17'4"	Timber	+0.3% WB	Tangent	0.3%	0.8%	7°30'	East	6400	2-4-2 66,640*	Portal
No. 2	Guernsey Wyo	1979	1	20'11	17'	"	+0.7% WB	"	None	0.8%	7°30'	"	6400	"	"
No. 3	Wendover Wyo	1442	1	21'8	17'	"	0.1% WB	"	None	0.8%	7°30'	"	6400	"	"

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Glenwoo
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TUNNEL	LOCATION	Length	Trks	Height	Width	LINING	THROUGH GRADES	TUNNEL ALIGNMENT	Reduction of Rul. Gr.	Ruling Grade	Max. Curvature	Dir. of Traf.	Avg. Weight Trains	Type & Tractive Power Operated	Ventilation
[illegible]	WESTERN	REGION				CHICAGO	ROCK ISL &	PACIFIC							
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	17	[illegible]	[illegible]	Tangent & 6°		0.[illegible]	6°00'	E&W	5100	Mikado 6[illegible],000*	Portal
No. [illegible]	[illegible]	[illegible]		[illegible]	18	Concrete	[illegible] 0.3% WB	Tangent & 6°		[illegible]	6°00'	E&W	5100	"	"
						DENVER &	RIO GRANDE	WESTERN							
[illegible]	[illegible]	[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	Tangent	None	+1.[illegible]% WB +3.0% EB	16°00 12°00	East	3000	2 8 8 2 131,000* + Helper	Portal
[illegible]	[illegible]	[illegible]	1	23	18	[illegible]	[illegible] 2% WB	Tangent & 2°	"	[illegible] +0.[illegible]% WB	12°00	E&W	3000	2 8 8 2 131,000*	"
[illegible]	[illegible]	[illegible]	1	23	17	Concrete	[illegible] WB	Tangent & 6°		[illegible] EB +0.[illegible]% WB	12°00	E&W	3000	"	"
[illegible]	[illegible]	2252		19	14	[illegible]	Level	Tangent & 3° 2[illegible]		+0.5% EB WB	12°00	Mt. [illegible]	4000	2 8-2 59,000*	"
[illegible]	[illegible]	[illegible]32[illegible]	[illegible]	[illegible]	14'	[illegible]	[illegible]	Tangent	"	-4.0% WB [illegible]% EB	16°00	East	1000	2 8 8 2 95,000*	
						DENVER &	SALT	LAKE							
No. [illegible]	[illegible]	[illegible]		[illegible]	16	[illegible] Timber	[illegible] WB			[illegible]		East	2400	Mallet [illegible]64,[illegible]*	Portal
No. [illegible]	[illegible]	1727	1	22	16	"	2% WB			2%	12°00	"	2400	"	"
No. [illegible]	[illegible]	[illegible]		22	16		[illegible]	Tangent & [illegible]		2%	12°00'	West	2400	"	"
No. [illegible]	[illegible]	[illegible]		22	16		2%			2%	12°00	East	2400	"	"
No. [illegible]	Volcano, "	[illegible]		22	16		+[illegible] WB	[illegible]° & Tangent		[illegible]	12°00'		2400	"	"
No. [illegible]	[illegible] "	[illegible]		22	16	"	+[illegible]	12°00'		[illegible]	12°00	"	2400	"	"
[illegible]	East Portal, "	[illegible]	1	22	16	Conc, [illegible]	+[illegible] -0.[illegible] WB	Tangent		2%	12°[illegible]	"	2400	"	Mech.
						SOUTHERN		PACIFIC							
[illegible]	[illegible]	[illegible]	1	[illegible]	[illegible]	Concrete	[illegible]	Tang Spiral 6°00		[illegible] WB [illegible] EB	6°1[illegible] [illegible]		3130	AC-5[illegible] [illegible]0,940*	Portal
No. 6	Summit, "	[illegible]	WB	18'2"	[illegible]	[illegible] Timber	+1.[illegible] WB	Tangent		[illegible]	6°00	West	4400	AC 6 AC 7 24,300*	Spratt
No. [illegible]	[illegible]	[illegible]	EB	[illegible]	15'	Timber & Conc	[illegible]	Tang. Spiral [illegible]		.5%	6°00	East	4400	"	Portal
No. [illegible]	[illegible]	[illegible]	EB	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] Spiral Tang		[illegible]	6°00	"	4400		"
No. [illegible]	[illegible]	1000	2	[illegible]	[illegible]	Concrete	+1.[illegible]	Tangent		1.5%	6°00	East	4400		"
No. [illegible]	[illegible] "	[illegible]248	EB	[illegible]	[illegible]	[illegible]	[illegible] EB	"		[illegible]	6°00	East	4400		"
No. [illegible]	[illegible]	[illegible]	EB	[illegible]	[illegible]	[illegible]	+.4[illegible] EB	[illegible]		1.5%	6°00	"	4400	"	"
No. [illegible]	[illegible]	[illegible]	EB	[illegible]	[illegible]	"	[illegible]	Tang & Spiral		[illegible]	6°00	"	4400	"	
No. [illegible]	[illegible]	[illegible]009	EB	21'	[illegible]	"	[illegible] EB	[illegible] Tang Spiral		1.5%	6°00'	"	4400		
No. [illegible]	[illegible]	[illegible]	WB	[illegible]	32'	Concrete	-[illegible]43 WB	[illegible]		[illegible]	10°00'	West	4400	"	"
No. [illegible]	Norden,	10,326	[illegible]	22'	17'	[illegible] Conc	[illegible]	Tangent		[illegible]	10°00	East	4400	"	"
No. [illegible]	Elmore,	1785	1	[illegible]	17'	Concrete	[illegible]	[illegible]		1.[illegible]	[illegible]°00		2500	"	"
[illegible]	Dorris,	2070	1	21'2"	17'	[illegible]	[illegible]	Tang. Spiral [illegible]		[illegible]	[illegible]		4000		
No. 2	[illegible]	[illegible]	1	21'2"	[illegible]		[illegible] EB	Tangent		-0.4[illegible]	4°[illegible]		4000	"	"
No. [illegible]	Siskiyou, "	3108	1	[illegible]	14	Timber	+2.[illegible] EB			3.3%	14°00		625	F[illegible] [illegible]50*	"
No. 4	Wall Creek	[illegible]	1	[illegible]	15	"	+0.2%, -1.16% EB	Tangent & 4°		3.3%	14°00		625	"	"
No. 2	[illegible]	1403	WB	20'[illegible]	16'4	"	+0.4%, Level EB	Tangent		1.35%	4°10	West	5000	F2 5 64,750*	"
No. 3	Ryndon,	2477	WB	21'1"	[illegible]	Conc & Timber	+0.4%, Level EB	"		1.35%	4°10	"	5000	"	"
No. 4	Ryndon,	2926	WB	20'[illegible]	[illegible]	Timber	+0.4%, Level EB			1.35%	4°10'	"	5000	"	"
No 5	Ryndon	1655	WB	21'[illegible]	17	"	+0.2%, Level EB	Tang, Spiral [illegible]		1.35%	4°10'	"	5000	"	"
No. 3	Cascade Summit	[illegible]655	1	21'	17	Conc & Timber	-1.6% EB	5° spiral Tang. Spiral		1.8%	8°00'	"	4600	Art Cons 124,300*	"
No. 7	Cruzatte	3164	1	22'	16'8"	" " "	-1.8% EB	6°00 Tang. 8°00		8°	8°00	"	4600	"	"
No. 9	Cruzatte "	1144	1	22	16'	Partly Conc	-1.8% EB	Spiral Tang Spiral 8°		1.8%	8°00'	"	4600	"	"
No. 11	Frazier	2121	1	22	16	Conc & Timber	-1.8% EB	6°00 Spiral Tang		1.8%	8°00	"	4600	"	"
No. 16	Fields	2213	1	22	16'9"	" " "	-1.8% EB	4°50		1.8%	8°00	"	4600	"	"
No. 22	Oakridge	1999	1	20'11"	16'10"	" " "	-1.80% EB	1°25 spiral Tang. Sp		0.98%	8°00	"	4600	"	"
No. [illegible]	[illegible] "	2811	1	17'8"	13'10"	Partly Conc & Timb	[illegible] EB	Sp Tangent Sp		2.28% WB 2.12% EB	12°00	E&W	1800	Art Cons 90,940*	"
No. [illegible]	Hugo, "	2105	1	18'8"	17'4"	Conc & Timber	[illegible]	Sp Tangent Sp		2.28% WB [illegible] EB	12°00'	E&W	1800	"	"
No. 13	[illegible] "	2489	1	20'11"	15'8"	" " "	+0.6%, 0.6% EB	8°00 Spiral Tang Sp		0.6%	10°00	West	2500	Cons 45,470*	"
No. 1[illegible]	[illegible]	2133	1	21'2"	15'11"	" " "	0.4% EB	Spiral, Tang		0.6%	10°00	"	2500	"	"
No. 1[illegible]	[illegible] "	1200	1	21'4"	16'1"	" " "	+0.4%, -0.3% EB	Tang Spiral, 2°00		0.6%	10°00	"	2500	"	"

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No 27	Isla
No 38	La
No 39	Ca
No 40	Tab
No 1	Al
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No 14	Car
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TUNNEL	LOCATION	Length	Trks	Hght.	Width	LINING	THROUGH TUNNEL		Reduction of Rul Gr.	Ruling Grade	Max. Curvature	Dir. of Traf.	Wgt. Hviest Trains	Type & Tractive Power Operated	Ventilation
							GRADES	ALIGNMENT							
[illegible]	[illegible]	[illegible]				SOUTHERN		PACIFIC							
No. [illegible]	[illegible], Ore			[illegible]	[illegible]	Concrete & Timb	[illegible] 0.2% EB	Tangent		0.6%	10° 00'	West	2500	Cons 45.470*	Portal
No. [illegible]	[illegible]	[illegible]		[illegible]	[illegible]	" "	[illegible] 0.26% EB	6° spiral, Tangent		0.6%	10° 00'	West	2500	"	"
No. [illegible]	[illegible]	[illegible]		[illegible]	16'	Timber	[illegible] EB	Tangent		+1.58%	10° 20'	East	3000	"	"
No. [illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible] & Timber	[illegible] EB	Tang 9°, Tang 9°		+1.33%	9° 00'	West	500	"	"
No. [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Brick & Concrete	[illegible] EB	Tangent		0.17%	10° 50	West	2250	GS 2 3 74.710*	"
No. [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	" "	+0.3% EB	0° 50, Tangent		0.17%	10° 50	West	2250	"	"
No. 3	[illegible]	[illegible]	[illegible]	[illegible]	29.8	" "	+0.10%, -0.25% EB	Tangent		0.17%	10° 50	West	2250	"	"
No. [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	" "	-0.1% Level EB	Tangent, & 1° 00		0.17%	10° 50	West	2250	"	"
No. [illegible]	[illegible]	[illegible]	2	21'8"	29.4	" "	Level	Spiral, Tang, Spiral		0.17%	10° 50'	West	4000	F (2-10-2) 75,150*	"
No. [illegible]	[illegible]	[illegible]	1	22'	17	Concrete	[illegible] EB	2° 00 Spiral Tang		[illegible]	5° 00	East	4000		"
No. [illegible]	[illegible]	[illegible]	1	[illegible]	16	Timb & Concrete	[illegible]	[illegible]		2.2%	10° 00	East	4000	"	"
No. [illegible]	[illegible]	[illegible]	1	[illegible]	[illegible]	" "	[illegible]	[illegible] Tang [illegible]		2.2%	10° 00'	East	[illegible]	"	"
No. 1	[illegible]	6207	1	[illegible]	15'7"	" "	[illegible]	Tangent		3.02%	16° 00	West	875	Consol 45 470*	"
No. 2	[illegible]	[illegible]	1	19'7"	[illegible]	" "	[illegible]	Tangent		3.02%	16° 00	West	1875	"	"
No. 5	[illegible]	[illegible]	1	22	16.6	Concrete	[illegible]	[illegible] Spiral Tang		[illegible]	16° [illegible]	East	3750	AC-63 16 900*	"
No. [illegible]	[illegible]	[illegible]	1	[illegible]	17'	Timber	[illegible]	Tangent		1.00%	6° 00	West	2400	F-63 75,150*	"
No. [illegible]	[illegible]	[illegible]	1	22	16	Concrete	[illegible]	Tangent		2.12%	6° 28	East	3750	Mallet 124 300*	"
No. 26	[illegible]	[illegible]	1	[illegible]	16	"	[illegible]	Tangent		[illegible]	6° 00	East	3000	F 4 10 2 75 150*	"
[illegible]	[illegible]		1	[illegible]	[illegible]	Timber	-1.0%	Tangent		[illegible]	6° 05	East	2675	[illegible] 63 84 200*	[illegible]
						NORTH	WESTERN	PACIFIC							
No. [illegible]	[illegible]	653	1		22'4"	[illegible] & Timber	-1.0% [illegible]	Tangent	None	[illegible]	6° 20'	North	1630	Consolidated 45 470*	Portal
No. 3	[illegible]	1105	2	[illegible]	[illegible]	" "	[illegible]	Tang & [illegible]° 30		[illegible]	3° 00	"	1630	[illegible]	"
No. 4	[illegible]	1309		[illegible]	[illegible]	Timber	[illegible]	Tangent		[illegible]	[illegible]		1600	"	"
No. 6	[illegible]	1762	1	[illegible]	[illegible]	Partial Timber	[illegible]	Spiral, Tang, Spiral		Level	9° 00	South	3250	[illegible]	"
No. 8	[illegible]	1270	1	[illegible]	[illegible]	" "	+0.1% -0.1% [illegible]	[illegible] Tang, Spiral		0.1%	10° 00	"	3250	"	"
No. [illegible]	[illegible]	[illegible]		17'	[illegible]	Conc & Timber	[illegible]	Tang & Spiral		[illegible]	8° 00	"	1750	Ten Wheeler 36 830*	"
No. [illegible]	Larabee,	1122	1	17'	[illegible]	Timber	[illegible]	[illegible] Tang	[illegible]	0.1%	8° 00	"	1750	"	"
No. [illegible]	[illegible]	1029	1	15'	19	"	[illegible]	Tang & [illegible] 00	[illegible]	Level	10° 00	"	1750	"	"
No. [illegible]	[illegible]	969	1	12'6	17	"	[illegible]	Tangent		1.0%	6° 00'	"	1450	"	"
No. 1	Alto	219	1	14	[illegible]	"	[illegible] 0.65% 0.4% [illegible]	Spiral Tangent		1.13%	5° 00	"	600	Ten Wheeler 32.490*	"
						SAN DIEGO	AND ARIZ.	EASTERN							
No. 8	[illegible]	[illegible]	1	21'11"	[illegible]	Partly Timber	-0.96% -1.4% -1.28 -1.16% EB	Spiral [illegible] 20° 0° 30 Tang [illegible] 6°		2.2%	20° 00	East	2171	Consolidated 45,470*	Portal
No. [illegible]	[illegible]	[illegible]	1	21	8.6	" "	[illegible] -1.4% EB	Spiral & Tang	[illegible]	2.2%	20° 00	"	2171	"	"
						UNION		PACIFIC							
Sherman EB	[illegible]	[illegible]	1	24'	16	Concrete	+0.27%, -0.3% EB	Tangent		0.82% EB WB	4° 00 EB 5° 06 WB	East	4100	Simple Mallet 99 840*	Portal
Sherman WB	[illegible]	828	1	24	16'	"	+0.27%, -0.3% EB	"		0.82% EB WB	4° 00 EB 5° 06 WB	West	4100	"	"
Aspen	Aspen [illegible]	5941	1	18'4"	16	"	-0.4% EB	"		0.82% EB WB	5° 15	East	4100	Mallet 106 900*	"
No. 3 EB	[illegible]	[illegible]	1	23'	16	"	+0.38% +1.16% EB	2° 00 & Tang		+1.14% EB	7° 02	"	3000	[illegible]	"
No. 4 EB	[illegible] Utah	[illegible]	1	[illegible]	16'	"	[illegible] EB	Tangent		+1.14% EB	7° 02	"	3000	"	"
No. [illegible] EB	[illegible] Utah	[illegible]	1	[illegible]	16	"	+1.00% EB	"		+1.14% EB	7° 02	"	3000	"	"
[illegible] Pass	[illegible]	1426	1	20'6"	16'	Conc & Brick	+0.25%, [illegible] EB	"		+1.55% EB +0.72% WB	6° 30	"	5000	"	"
No. 6	[illegible]	[illegible]	1	21'6"	17'	Timber	EB 0.6%	4° 00		[illegible] EB [illegible] WB	0° 00	"	—		"
No. 18	[illegible]	[illegible]	1	21	16	Concrete	[illegible] EB	Tangent		[illegible] EB [illegible] WB	[illegible] 00	"	8025	2-10-2 70 450*	"
No. [illegible]	[illegible] Wash	[illegible]	1	[illegible]	[illegible]	Timber	EB [illegible]	[illegible]		+0.5% EB +0.3% WB	6° 00	"	5920	"	"
No. 11	[illegible] Wash	[illegible]	1	22'	[illegible]	"	EB [illegible]	Tang & 1° 00		+0.6% EB WB	10° 00	"	4000	"	"
No. 4	[illegible], Nev	[illegible]	2	[illegible]	30'7"	Concrete	EB [illegible]	Tangent		[illegible] EB [illegible] WB	8° 00	West		"	"
No. 11	[illegible] Nev	1324	2	[illegible]	[illegible]	"	EB [illegible]	4° 00 & Tang		[illegible]	10° [illegible]	"		"	"

SHEET 9

TUNNEL	
CENTRAL	K
A	Sa (F
No 1	Ni
No 23	Be
No 33	Ke
No 35	Sp
No 6	Mo
No 37	Ch
No 39	Ch
No 41	Ca
No 42	Ho
No 43	Ja
SOUTH	W
Gray Summit	Gra
Reeds Spring	Re
Crest	Cr
Cricket	Cr
Cotter	Co
Conway	Co
Winslow	W
Jenson	J
St Louis	S
Mt Royal	M
St Clair	Po Sa
M.P. 48.1	Re
MP 10.2	Tr
MP 54.9	B
MP 21.7	S
MP 26.0	Y
MP 40.8	B
MP 14.8	U
MP 74.9	K
Quebec	W
Brockville	B
Spiral No. 2	C
Connaught	G
Spiral No. 1	Y
MP 89.5	7
Long	S
Vancouver	V
Bulldog	7
MP 114.0	A
No. 8	F

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NAME	LOCATION	Length	Trks	Height	Width	LINING	THROUGH TUNNEL GRADES	ALIGNMENT	Reduction of Rul. Gr.	Ruling GRADE	Max. Curvature	Dir of Traf	Wgt. Hviest Trains	Type & Tractive Power Operated	Ventilation
[illegible]	WESTERN	REGION				WESTERN		PACIFIC							
[illegible]	[illegible]	[illegible]		[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	West		Switcher 24 4[illegible]#	Portal
[illegible]	[illegible]	[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	"	2200	2-8-2 60 300#	"
[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	"	[illegible]	[illegible]	[illegible]	[illegible]	10°00'	East	4000	2-8-8-2 50 300#	"
[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4000	"	"
[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.0%	0°00	"	4000	"	"
[illegible]	[illegible]	[illegible]	1	[illegible]	8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10°00	West	3200	2-6-6-2 80 000#	"
[illegible]	[illegible]	[illegible]		21	[illegible]	[illegible]	[illegible]	Tangent	0.3%	+0.8%	8°00	East	2850	2-8-2 60 300# +11 000#	"
[illegible]	[illegible]	[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		5000	"	"
[illegible]	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	Tangent	[illegible]	[illegible]	[illegible]		5000		"
[illegible]	[illegible]	[illegible]	1	[illegible]	[illegible]	"	[illegible]			[illegible]	[illegible]	"	5000	"	"
[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	"	0.4%	[illegible]	10°00		[illegible]	4-6-6-4 99 600#	"
SOUTH	WESTERN	REGION				MISSOURI		PACIFIC							
[illegible]	[illegible]	[illegible]		[illegible]		[illegible]	[illegible]	Tangent		[illegible]	[illegible]	E&W	5000	2-10-2 96 600#	Portal
[illegible]	[illegible]	[illegible]		[illegible]		[illegible]	[illegible]			[illegible]	[illegible]	N&S	2500	2-8-2 68 575#	"
[illegible]	[illegible]	[illegible]		[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	"	2500	"	"
[illegible]	[illegible]	[illegible]		[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]		"
[illegible]	[illegible]	[illegible]	1	[illegible]		[illegible]	[illegible]	Tangent		[illegible]	[illegible]		2500	"	"
[illegible]	[illegible]	[illegible]	1	[illegible]		"	[illegible]	"		[illegible]	[illegible]	"	4800	2-10-2 72 300#	"
						ST LOUIS	— SAN	FRANCISCO							
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Tangent	None	[illegible] NB [illegible] SB	8°00	N&S	1500 S 725 N	2-8-0 49 000#	Portal
[illegible]	[illegible]	[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	"	"	[illegible] NB SB	6°00	"	800 SB 900 NB	"	"
						TERMINAL	RR ASSOC	ST LOUIS							
[illegible]	[illegible] Mo	[illegible]	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] Tang	None	[illegible] EB WB		East	1750	0-6-0 49 300#	Mech.
	CANADA					CANADIAN		NATIONAL							
[illegible]	[illegible]	[illegible]	2	[illegible]		[illegible]	[illegible]	[illegible] Tangent [illegible]		[illegible]	Passenger Only	E&W		Electric 4 500#	Portal
[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible] EB	Tangent				East	2000	Electric 23 300# & 62 205#	"
MP 4[illegible]	[illegible]	[illegible]		22'	13 8	[illegible]	[illegible]	Tang [illegible] Tang	None	+0.7% EB +0.4% WB	10°00		2525	Santa Fe 62 000#	"
[illegible]	Tranquille, [illegible]	[illegible]			[illegible]	[illegible]ed	+0.[illegible]	[illegible] Tang [illegible]		0.4% EB WB	8°00'		4430	Consol 40 000#	"
[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		0.4% EB WB	8°00	"	4430	"	"
[illegible]	[illegible]	[illegible]	1		[illegible]	[illegible]	-0.25%	[illegible] Tangent [illegible] Tangent		0.4% EB WB	9°00	"	2920	Consol 50 000#	"
[illegible]	Yale,	[illegible]		[illegible]	[illegible]	[illegible]	+0.21% -0.2%	Tangent		0.4% EB WB	9°00	"	2920	"	"
[illegible]	[illegible]	2067	1	[illegible]	[illegible]	[illegible]	[illegible]	Tang Sp 6 00		0.4% EB WB	6°00	"	2715	Consol 40.000#	"
[illegible]	Usk,	[illegible]		21	[illegible]	"	Level -0.3%	Tangent		0.3% EB 0.23% WB	6°00	"	3140	"	"
[illegible]	[illegible]	[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] 6° Tan 6° Tan 6°		0.4% EB 0.23% WB	6°00'	"	4210	"	"
						CANADIAN		PACIFIC							
Quebec	[illegible]	5288	1	[illegible]	[illegible]	Concrete	+0.8% WB	Tang & 12° [illegible]		0.8%	12°00	West	1676	4-6-4 46.000#	Portal
Brockville	Brockville Ont	720	1	[illegible]	16	Partly [illegible]	0.91%	Tangent	None	Freight	Spur		400	Mogul 20.500#	"
Spiral No 2	Cathedral B.C	2922	1	[illegible]	[illegible]	Conc & Timber	-1.62% WB (6°00) [illegible] WB, Tang	10° & Tangent	0.2%	+2.2% EB +1.3% WB	10°00'	E&W	2350	2-8-2 plus 2 (2-10-2)s	"
Connaught	Glacier, B C	26[illegible]	2	20'6"	[illegible]	Reinf Conc	+0.95% WB	Tang, [illegible]00 spiral	Summit	2.2% EB WB	10°00'	"	4200	2-10-4 plus 2 center eng + pusher	Mech
Spiral No 1	Field, B.C	3255	1	21'6"	16'4"	Conc & Timber	1.62% WB	10° and spirals	0.2%	+2.2% EB +1.75% WB	10°00'	"	2350	2-8-2 plus 2 (2-10-2)s	Portal
MP [illegible]	[illegible] B.C	1147	1	[illegible]	16	Partly Timber	Level	Tang & spirals	Not on	+1.2% EB WB		West	3500	2-8-0 + pusher WB	"
Lena	Spuzzum, B.C	1457	1	19'	15'4"	Unlined	+0.47% WB	Tangent	"	+1.4% EB +1.0% WB		E&W	1920 E 2175 W	2-8-2	"
Vancouver	Vancouver B.C.	[illegible]	1	[illegible]	[illegible]	Concrete	[illegible]	[illegible] Tang [illegible]	"	Yard	Trkage			Switcher	Mech
Bulldog	Tunnel, B.C	2921	1	[illegible]	14'3"	Conc Portals	[illegible] WB	[illegible] Tang, 10°00	"	+2.2% EB WB		West	1575	2-8-0 plus Center Eng & Pusher	Portal
MP 114 [illegible]	Adra, B.C	1604	1	22'	18'3"	Partly Timber	1.2%, 1.3% WB	Tang & 10° 00	0.5%	+1.0% WB +2.2% EB		"	1945	2-8-0 + Pusher EB	"
No 6	Princeton, B.C	1011	1	22'6"	18'	Timber	+0.8% WB	Tangent	Not on	+2.2% EB WB		"	1070	2-8-0 plus pusher	"

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NAME	LOCATION	Length	Track	Height	Width	LINING	THROUGH TUNNEL GRADES	ALIGNMENT	Reduction of Rul.Gr.	Ruling Grade	Max. Curvature	Dir. of Traf.	Wgt. Hviest Trains	Type & Tractive Power Operated	Ventilation
	MEXICO														
						FERROCARRIL	SUD PACIFICO	de MEXICO							
[illegible]	[illegible]	[illegible]		[illegible]		[illegible]	Level	Tangent	None	[illegible] SB	[illegible]	South	000	MK 57 52 990*	Portal
[illegible]	[illegible]	[illegible]		[illegible]			[illegible]	"		[illegible] SB	9°00	"	1000	'	"
[illegible]	[illegible]	[illegible]		[illegible]		[illegible]	[illegible]			[illegible]	[illegible]	"	1000	'	"
[illegible]	[illegible]	1185					[illegible]	[illegible]	"	[illegible] SB	9°00	"	1000	"	"
[illegible]	[illegible]	[illegible]		[illegible]			[illegible]	[illegible]		[illegible] SB	9°00	"	1000	"	"
[illegible]	[illegible]	[illegible]	1	[illegible]	16'	[illegible]	+1.0% SB	"	.	+1.5% SB	9°00	'	1000	"	"
[illegible]	[illegible]	[illegible]		[illegible]		[illegible]	[illegible]	Tang & 3°00	"	+1.5% SB	9°00	"	1000	"	"
						MEXICO	NORTH	WESTERN							
[illegible]	[illegible]	[illegible]		[illegible]	16'	[illegible]	[illegible]			+3.0% SB [illegible]	10°30'	N&S	240 SB 400 NB	Small mountain type	Portal
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]			[illegible] [illegible] NB	0°30 8°10	"	300 SB 620 NB	" " "	"
MISC	ADDENDA														

Conclusions

1. In the location and design of new tunnels consideration should always be given to securing the advantageous and economical tunnel grade, taking into account as an important, but not necessarily controlling factor, the increased capital costs of securing a reduced grade, as compared with the capitalized savings, through improved operation and maintenance which may result therefrom.

2. While no hard and fast rule as to the desirable reduction of grade through proposed tunnels and adjacent thereto is possible, because of varying conditions of terrain, ventilation, drainage and operation associated with every tunnel, or sequence of tunnels, taking into consideration proper drainage, the rate of grade through proposed tunnels should be kept as low as is economically practicable. As a working basis for comparative study of proposed grades through tunnels exceeding 1,000 ft. in length, such grade should not exceed 75 percent of the ruling grade of the district, and this reduced grade should be extended for the full length of a tonnage train, but not less than 3,000 ft. below the tunnel and one-half that distance above the tunnel.

3. Comparative studies should be made for greater and less reductions of the proposed grade, in order to ascertain the most suitable grade, within and adjacent to the proposed tunnel. It can be reasonably assumed that the proper percentage of grade reduction for a long tunnel may be greater than for a short tunnel.

4. Summits within tunnels should be avoided, if possible, in the interest of efficient ventilation.

5. The alinement through proposed tunnels should, of course, be restricted as to curvature as much as is economically practicable, and if curvature is required the regular compensation for such curvature should also be introduced.

Recommendation

It is recommended that this report be received as information, the conclusions be printed in the Manual, and the subject discontinued.

Report of Committee 25—Waterways and Harbors

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J. L. Starkie
A. B. Stone
W. R. Swatosh
Edwin F. Wendt
J. E. Willoughby
S. L. Wonson
Committee.

To the American Railway Engineering Association:

Your committee respectfully reports on the following subjects:

1. Revision of Manual. No changes.

2. Breakwaters, bulkheads and jetties. Final report (Appendix A) presented as information, with definitions for Breakwater, Bulkhead and Jetty, for inclusion in the Manual.

3. Warehouse piers, coal piers, car float piers and others on the Great Lakes and seacoast, collaborating with Committee 6—Buildings and Committee 14—Yards and Terminals. Final report (Appendix B) on this subject presented as information.

4. Economic principles involved in clearances over navigable waterways. Progress in study—no report.

5. Seawalls and ocean shore protection, including effect of wave action and ice. Progress in study—no report.

6. Reasonable life of steel casings immersed in sea water. Subcommittee waiting for information on U. S. War Department tests. Progress in study—no report.

7. Selection of type of construction of piers in various kinds of water, including materials used therein. Final report (Appendix C) presented as information.

8. Lands subject to servitude of navigation as affecting protection of roadbeds built or to be built on proposed dam pool areas. Progress in study—no report.

The Committee on Waterways and Harbors,
G. P. Palmer, *Chairman.*

Appendix A

(2) Breakwaters, Bulkheads and Jetties

C. U. Smith (chairman, subcommittee), Benjamin Elkind, G. A. Knapp, A. N. Reece, E. H. Roth, G. R. Smiley, A. B. Stone, J. E. Willoughby.

Definitions

One of the specific assignments to this subcommittee is the development of a proper definition for the term "bulkhead". Reference to that old standby, Webster, shows "bulkhead" defined as follows: "A structure of wood or stone to resist the pressure of earth or water; a partition wall or structure, as in a mine; the limiting wall along a waterfront." The last part of this definition co-ordinates with our own association's definition of "bulkhead line" which is: "A line in a harbor defining the channelward limit of solid fills and bulkheads."

Bulletin 413, November, 1939.

The American Association of Port Authorities has defined a bulkhead as follows: "A retaining wall to prevent sliding of earth or fill into the water." This closely resembles the first part of the Webster definition although quite definitely materials of construction are not confined to "wood or stone."

In view of the above, the following definition of "bulkhead" is recommended for consideration for insertion in the Manual:

BULKHEAD.—An engineering structure to prevent sliding of natural ground or fill material into the water; the limiting wall or structure along a water front.

As the Glossary now published in the Manual of the Association does not include—"breakwater" or "jetty" and as these are subjects for this subcommittee, it appears proper to suggest definitions and they are herewith submitted with recommendation for approval (for insertion in the Manual).

BREAKWATER.—An engineering structure to afford shelter from wave action.

JETTY.—An engineering structure at the mouth of a river, at the entrance of a harbor or elsewhere, to control the water flow and currents, to maintain depth of channel, to protect harbor or beach.

History

From the very origin of harbors, breakwaters, bulkheads and jetties have been intimately associated with harbor work. Breakwaters and piers are very closely associated. Some definitions tell us that a pier carried into deep water becomes a breakwater, and a breakwater joined to the shore and formed with a road on top, becomes a pier. Where the protected side of a breakwater is used as a quay, or wharf, such breakwater is also known as a mole. Such construction is very infrequently referred to in this country, but is quite common in European countries. A bulkhead may often be a wharf and a jetty may develop into a landing wharf or pier.

For the purpose of this report, this close association of the structures in question to piers and wharves, is not considered, each of the three being analyzed exactly in accordance with the definitions above noted.

Analysis

Breakwaters

Use.—The ordinary use of a breakwater is as a wall or structure to protect water areas for the purpose of providing adequate and safe mooring in the event of heavy storms and to provide a place for the handling of shipping. Breakwaters are most important where artificial harbors are required in the development of a port. Breakwaters in addition, are sometimes used to furnish additional protection for interior areas adjacent to the main body of protected water.

In some instances, breakwaters or adaptations of them, are used along the shore line to prevent deterioration by reason of wave action. The breakwaters described herein are those that are used in connection with harbor protection.

Design.—There are three general types of breakwaters which may be described as those where the exposed face is:

1. Vertical
2. Partially vertical and partially inclined, and
3. Wholly inclined

A special type used where specific conditions are to be met but generally in connection with the use of a breakwater as a seawall, is where the exposed face is curved.

The selection of the proper type depends upon the conditions encountered at the site of the structure. Attention is called to what may be anticipated in connection with the three general types:

1. Vertical. This type is subject to severe wave impact and must be so designed that such wave impact will not destroy the structure.
2. Combination. Wave action against this type causes large volumes of water to be thrown practically vertical, which water will fall on top of the structure or behind any parapet that may be on it. There are histories of timber cribs which have been so seriously damaged by this action as to require replacement.
3. Inclined. If this is not carried high enough above the mean water level and surmounted by a parapet, waves will go over it and cause rough water on the site that is supposed to be protected.

It is well to note that in some types of breakwaters which do not actually function to break the wave action, waves striking such breakwaters obliquely are reflected back into the main body and in this reflection often accumulate size and energy. As an example of this, shipmasters have reported that they have noted the effect of reflected wave action from the Milwaukee (Wisconsin) breakwater as far out as two miles from the structure.

In the design of breakwaters, there are certain definite things that must be carefully considered. These may be listed as follows:

1. Winds. Direction and force of prevailing winds should be carefully observed and noted in any instance.
2. Currents. The characteristics and force of currents should be observed and their probable effect on the structure studied.
3. Waves. The height, characteristics and force of waves should be carefully observed and their action on the proposed structure should be properly estimated.
4. Ice Hazards. In those localities where ice occurs, investigations should be made to determine the effect of ice and of alternate freezing and thawing on the structure.
5. Foundation. Wherever a breakwater is to be placed, the type and character of the bottom should be carefully determined so that the structure can be properly founded.
6. Materials. The availability and cost of materials proposed to be used in the structure should be carefully studied to determine the economic properties of the design.

Construction.—Having determined the type of breakwater required for a specific set of conditions, consideration must then be given to the construction requirements. There are several characteristics of construction which have been generally used and are considered quite common practice.

Rubble Mound. A rubble mound breakwater is constructed with the use of cobble, rip rap and rubble stone dumped from scows or barges or from cars moving over a temporary construction trestle. The usual procedure in this type of construction is to build up with small stone in the inside, gradually increased in size until the outside face is reached. This face may be stone-paved or it may be finished with heavy rough rubble stone of considerable unit weight. In some instances, this type of breakwater has been constructed with a sand core but there are records of where this core has ultimately washed out, smaller stone displacing the sand and in the end, the larger stone displacing the smaller stone, causing a complete failure of the structure. The subcommittee is of the opinion that this type of breakwater, if finished with large rough stone, roughly placed so as to present a rough, rugged and uneven face to wave action, is the best type to assure breaking up the wave action, which is the desired result. This type also permits of water seeping through it so that there is not a surge created as there is with some types of breakwater. Great care must be used in the selection of the stones and in their placement. There have been many instances where breakwaters subject to severe wave action, have had the larger stones washed away. This type of breakwater is quite costly and its cost increases at a very rapid rate with increase in depth of water.

Timber. This type of breakwater has been extensively used on the Great Lakes and may consist of timber cribs, floated over a rubble mound foundation, the cribs being sunk by the addition of stone fill within them. Another type involves the use of wood round piles and sheet piles driven in place and stone filling placed between the walls as constructed. In this type of construction, rip rap is frequently placed along the outside to provide added protection.

Masonry on Stone Mound. This type consists of stone or concrete masonry built up on top of a rubble mound providing merely a cap or additional protection to the previously described rubble mound type.

Masonry Wall. This type is built up with systematic courses of stone masonry or concrete. If constructed in the dry, cofferdams are generally used or this type may be constructed by the use of divers or diving bells in the water. Careful study should be given to this type and the type above mentioned to be assured that the wave action will not compact air beneath the concrete causing the top to blow off, which has frequently happened.

Reinforced Concrete. Reinforced concrete is used in the construction of cribs or caissons generally built on shore, floated into place over previously prepared stone foundations and filled with either concrete or stone and protected by rip rap on the outside. This type is sometimes built up from a natural bottom foundation. Reinforced concrete piles and sheet piles are sometimes used in the same manner that timber is in a type as previously mentioned under timber above.

Bulkheads

Use.—Bulkheads are used in connection with beach and shore protection structures but the most general use is in the construction of port works such as quay walls, docks and piers.

Design.—It can hardly be stated that bulkheads are confined to any particular type or types. Their design varies with the conditions to such an extent that they are too numerous to specify.

It can be stated, however, that in general, bulkheads are confined to the following general types of construction:

1. Timber round piles and wood sheet piles with adequate wood pile anchorage.
2. Steel sheet piles in place of wood sheeting either in combination with wood piles or steel sections.
3. Stone masonry or concrete on pile or natural foundations.
4. Various combinations of the above, including relieving platform type of construction.

Construction.—Construction is so variable that it does not warrant a description in a report of this character. The design and construction must meet the local conditions and in some instances, these are such that the economics of the situation may call for a type of structure that in itself appears to be expensive.

Jetties

Use.—Jetties are used to protect harbors and beaches, river mouths and waterway entrances; to control water flow and currents and to maintain depths in waterways.

Design.—The design of jetties absolutely depends upon the local conditions. Wherever jetties are to be used, the purpose is to create a certain condition or to attempt to perpetuate one. This obviously requires a specific design for the situation.

Jetties in general are divided into groups designated as:

1. Single curved
2. Single straight
3. Twin curved
4. Twin straight
5. Open at shore end
6. High and low

Construction.—Jetties are generally constructed of mounds of rubble stone in much the same manner as described for rubble mound breakwaters. As they are almost always built up from the natural bottoms, it is essential to determine the character of bottom so as to properly estimate the volume of stone that may sink into the bottom at the start of the work.

Other types of jetty construction include fascine or mattress work with stone topping and also wall work and reinforced or plain concrete.

Argument

As local conditions have so important a part in the determination of the proper usage of breakwaters, bulkheads and jetties, this subcommittee does not feel that it is in a position to analyze the advantages and disadvantages of any types for these structures and accordingly makes no recommendation as to practice.

Conclusions

Breakwaters.—Breakwaters at most of the harbors of this country are generally constructed by the government engineers. It is only in unusual cases that private interests find it necessary to undertake their construction. Where the government is doing the work, it is recommended that interested parties contact the local U. S. district engineer and arrange to be heard as to their opinions. Where private interests are doing the work, it is recommended that after all available data have been obtained through adequate surveys and investigation, that the U. S. district engineer be consulted and requested to give an opinion before the final plan is accepted.

Bulkheads and Jetties.—As the conditions under which these facilities are constructed vary to such a wide degree by reason of the local requirements, no definite conclusions are offered. Where these structures are to be built, careful investigations and exhaustive surveys should be carried out before the design is attempted or the work started.

It is recommended that (1) the definitions in this report be included in the Manual; (2) the balance of the report be received as information; and (3) the subject be discontinued.

Appendix B

(3) Warehouse Piers, Coal Piers, Car Float Piers and Others on the Great Lakes and Seacoast

W. R. Swatosh (chairman, subcommittee), Benjamin Elkind, George F. Hand, W. G. Nusz, V. B. W. Poulsen, C. U. Smith, J. L. Starkie, S. L. Wonson.

Transfer Bridges and Other Facilities

In order to complete its assignment, the final report of Subcommittee 3 will cover "Transfer Bridges and Other Facilities".

The report covers in a descriptive manner the general features encountered in the design and construction of "Transfer Bridges and Other Facilities" serving a similar purpose. A transfer bridge functions as a medium for transmitting railroad cars from rails on land to rails on car floats or ferries or vice versa.

There are several types of transfer bridges in general use, namely, those known as "pontoons" generally single-span, and those known as "electric bridges" of either single or multiple-span construction. Multiple-span construction is used where changes in water elevation vary so greatly that an adjustment to those elevations cannot be accomplished with single-span construction.

In order to guide a car float so that it can be easily moored to the bridge, pile or crib racks are installed which form a slip and also act as side guides for steering the unloading end of such crafts to the transfer bridge. The outshore ends of the racks are protected by pile clusters.

The usual type of transfer bridge construction is impracticable on the Mississippi river as it has extreme variations in its water elevations. For example, at Vicksburg, Miss., the extreme variation in water elevations is approximately 60 ft. To overcome such conditions, traveling cradle systems are used at several points on the river.

Pontoon Transfer Bridges for Car Traffic

Usually the inshore end of the bridge is fastened and operated on rocker bearings; the outshore end being supported and fastened on a pontoon. The use of a pontoon to overcome fluctuations in water elevations usually eliminates the necessity of installing expensive machinery and its appurtenant construction. The mere fact that a bridge operates in this manner is not in itself sufficient to adjust the floor elevation of the bridge with the floor elevation of the car float, for the pontoon may have a slightly greater buoyancy than the craft.

Timber or metal gallows frames are constructed over the outshore end for the purpose of raising the bridge. These frames are placed on timber or concrete foundations supported on piles. Vertical guides are installed to prevent side sway when connecting a craft and also to guide the bridge when it is being raised or lowered. Cross members of the gallows frame support a steel shaft on which winding drums are mounted carrying counterweighted chains attached to the bridge and passing around a drum on which is fastened a type of helm wheel with hand spokes. The lifting is effected by turning the helm wheel. Two such wheels are mounted on the bridge; one on each side. The raising of the bridge is performed manually by bridgemen and when it has reached the desired elevation the wheels are dogged, remaining so until such time as it may be necessary to make further adjustment in the bridge elevation.

The raising of this type of bridge is also accomplished by the use of electric or steam power instead of man power, as described, and also by dewatering the pontoon by the use of a pump.

Where car floats are handled by this type of bridge, it has as a rule two tracks and a switch to permit the loading of car floats having three tracks. When a loaded float is docked it is necessary to bring the tracks on both the bridge and the float to the same elevation. To accomplish this, it is generally necessary for an engine to back a weighted car onto the bridge and sink the pontoon to the proper elevation. This arrangement is used so that in loading or unloading floats, it will be unnecessary for the engine to go onto the bridge. Sometimes the lowering of a bridge is accomplished by pumping water into the pontoon.

The weighted-car operation takes approximately ten minutes, it being necessary first to sink one side of the bridge to the elevation of the car float, at which point it is held with a cast steel toggle bar sliding in pockets fastened to bridge floor and boat deck. The engine generally has three cars ahead of it (one of them weighted), then crossing over to the other side where the same operation is carried out.

Electric Powered Transfer Bridges for Car Traffic

The substructure of an electric bridge generally consists of a pile foundation supporting a timber relieving platform at the shore end on which there is constructed a concrete bulkhead retaining the fill approach to the bridge. The concrete bulkhead is usually designed so it also can be used as an anchorage for the shore end of the bridge. In most cases the outshore end of the bridge together with the lifting and lowering mechanism and counterweights are suspended from a structural steel frame founded on concrete piers resting on pile foundation. In some instances batter piles are driven to further increase lateral stability in pile foundations.

The electric bridges are of newer design, being considered more flexible and efficient than the older pontoon type for the handling of car floats. The average time consumed to make floats fast to these bridges approximates two minutes.

The condition of the tide or the manner in which a float is loaded does not affect the operation of this type of bridge, as each side can be operated separately and there is also an apron on each which is raised or lowered independently. The most common type is a two track apron.

Design

The design of the relieving platform, bulkhead, piers and bridge structure depends a great deal on local conditions and the length of bridge and type of car traffic. In general, pontoon bridges are constructed of steel beams or wood trusses. Electric bridges are of fabricated structural steel. The bridges are designed for engine and car loading, ranging up to 110 ft. in length for single spans and 300 ft. for multiple spans. The vertical lift of the bridges is designed to overcome the fluctuations of water elevations, which in tide water districts approximates 12 ft. In lake districts the water level varies seasonally, the maximum variation being about 10 ft.

General

In 1931 the Yards and Terminals committee assembled information on the "Design and Operation of American Rail-Water Terminals". This information was never published, but is on file in the office of the secretary of the American Railway Engineering Association. The following are excerpts from the information on "Transfer Bridges" assembled by that committee:

Type of Construction	*Transfer Bridges Reported at Terminals*		
	Ocean	*Lake*	*River*
Timber throughout	7	2	
Wooden float	1		
Timber and steel on concrete	1		
Steel piling and steel apron		1	
Truss	1		
Transfer bridge	1		
Through girder bridge and pontoon	1		
	12	3	

Type of Transfer Bridge or Apron

Type and Material			
Wooden truss hinged to pontoon	1		
Steel	6	2	
Steel frame, wood deck	3	1	
Pontoon	1		
Hinged rocker	1		
	12	3	

Method of Adjustment			
Electric	1		
Hydraulic	2		
Counter balanced		1	
Not reporting	9	2	
	12	3	

Derailments—Causes and Remedies

Causes	*Ocean*	*Remedies*	
Heavy load and stiff trucks	1	Anti derailer	1
Non-alinement of rails	1	None	1
Non-alinement of rails	1	Replacement of wooden barge with steel and heavier track	1
Loose wedges	1	Tighten wedges	1
Shifting of floats	2	Greater care	2
Excessive grade	1	No report	1
No report	5	No report	5
	12		12
	Lake		
Heavy load and listed ferry	1	Slower speed	1
Failure to remove dogs from rail	1	No report (assume greater care)	1
Sharp curve and list of ferry	1	Guard rail	1
	3		3

Attention is called to Association's Bulletin No. 387, published July 1936, containing a treatise prepared by Mr. E. E. R. Tratman on "Railway Car Ferries; American and Foreign" which contains much detailed information and illustrations on both domestic and foreign transfer bridges and on the cradle and incline systems used on the Mississippi river.

Conclusion

The committee is of the opinion that the design of transfer bridges and other facilities of similar nature depends upon so many variables that each layout must be determined by local requirements and the type of traffic to be conveyed by them and that the structure must be planned to meet these conditions.

The committee recommends that this report be received as information, that the treatise by Mr. Tratman above referred to be reprinted in the Proceedings for 1940, and that the assignment be discontinued.

Appendix C

(7) Selection of Type of Construction of Piers in Various Kinds of Water, Including Materials Used Therein

George F. Hand (chairman, subcommittee), Benjamin Elkind, R. P. Forsberg, H. S. Loeffler, W. G. Nusz, A. N. Reece, G. R. Smiley, S. L. Wonson.

A questionnaire to develop information in answer to the assignment was sent to all members of Committee 25. The replies have been tabulated and the subject has been thoroughly discussed among the members. The committee does not find any relation between "type of construction of piers" and the "kind of water" in which they have been built; neither does it find any justification for the assumption that specific types of pier construction should or can be designed as most suitable for specific kinds of water.

Types of pier construction may be classified as follows:

Pile and timber, open construction
Solid fill retained by seawalls or other types of bulkheads
Solid fill on relieving platform, with seawalls or other types of bulkheads
Solid fill with pile and timber extension or apron

Kinds of water may be classified as follows:

Salt water
Fresh water, either river or lake
River water, where tide ebbs and flows, of different degrees of salinity

Any of these waters may be polluted by sewage or industrial wastes at specific locations. Marine borers infest most salt water, and may be found in water of comparatively low salinity or polluted water, and even in very cold temperatures.

Actually, all of these types of construction, with various combinations and modifications, have been built in all of these kinds of water. Certain localities are given to certain types, largely governed by easily available materials and their low cost and sometimes by long established custom.

The type of pier construction generally depends not on the kind of water, but on depth of water, use to which pier is to be put, general conditions of bottom and shore, degree of permanency desired, and the amount of money available. In other words, the economics of each situation will govern.

The materials used will depend on the same considerations, with the added one of the possibilities of marine borers in salt or partly salt water. There is the further consideration of fire hazard in the selection of materials. Recent experience and investigations show that borers now infest waters where previously there had been only sporadic, light attacks, and waters thought to be immune because of pollution or low temperatures.

Two factors have operated to increase and extend borer attacks, viz; decrease in sewage in the vicinity of cities or even relatively small centers of population through construction of sewage disposal works, and the breeding of hardy colonies of borers that defy pollution, low temperatures, and low salinity. It is clear that, in salt water, materials immune to borer attacks should be used below mean high water unless careful and extensive investigations show no likelihood of borers within the expected life of the structure. Extensive investigation and experimental installations show that so far the only wood preservative known to be effective against borers is creosote oil in sufficient quantity and with thorough penetration.

Piles may be of wood (treated or untreated), concrete, or steel. Bulkheads of solid fill piers may be of stone, concrete, wood crib, wood or steel sheathing. Cribs preferably should be filled with stone. Relieving platforms on piles may be of wood, concrete or stone, or reinforced concrete, and the seawalls or bulkheads on them of stone, concrete or wood crib. Timber used in framing or in cribs may be treated or untreated. Timber platforms are usually treated. Fill may be dredged material, cinders or other available material.

This report is submitted as information, with recommendation that the subject be discontinued.

Report of Committee 6—Buildings

L. H. Laffoley, *Chairman,*
C. M. Angel
G. A. Belden
E. Christiansen
H. M. Church
H. G. Dalton
A. G. Dorland
W. T. Dorrance
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C. H. Sandberg
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E. W. Scripture, Jr.
L. W. Smith
A. L. Sparks
A. B. Stone
O. G. Wilbur
Committee.

To the American Railway Engineering Association:

Your committee respectfully reports on the following subjects:

1. Revision of Manual (Appendix A).

2. Preparation of specifications for railway buildings. No report.

3. Requirements and design of garage buildings for railway service. Progress in study—no report.

4. Railroad warehouse requirements for handling quick frozen products. No report.

5. Drinking water facilities in railway buildings, collaborating with Committee 13—Water Service, Fire Protection and Sanitation (Appendix B). Complete and presented as information.

6. Drop pits—jacks and tables (Appendix C). Complete and recommended for publication in the Manual.

7. Methods of determining the protective and economic value of paints. Progress in study—no report.

8. Refrigerator equipment for cold storage houses and rooms. No report.

The Committee on Buildings,
L. H. Laffoley, *Chairman.*

Appendix A

(1) Revision of Manual

G. A. Belden (chairman, subcommittee), W. T. Dorrance, F. R. Judd, C. H. Sandberg, O. G. Wilbur.

The committee recommends that the first sentence in the first paragraph of Section 110, under General Conditions, in the Specifications for Railway Buildings, on Manual page 6–3, be revised to read as follows:

All work shall conform with the Federal, State or Municipal laws, ordinances or regulations governing such work.

The committee recommends that the present Specification for Structural Steel and Iron, as published in the Manual, Section XII under Specifications for Railway Buildings, pages 6–47 to 6–67 inclusive, be withdrawn, and the following new specification be adopted to replace it. This specification was prepared by a special subcommittee consisting of members of Committees 6 and 15, as follows: F. R. Judd, chairman, E. Christiansen, A. C. Copland, C. H. Sandberg, A. B. Stone, J. Jones, C. E. Sloan and J. B. Hunley.

Bulletin 414, December, 1939.

XII

1201. STRUCTURAL STEEL AND IRON

A. General

1. Scope

(a) Under this heading shall be included the furnishing, fabrication, erection, inspection and in some instances the design of all structural steel and iron as shown on drawings, specified or implied as being necessary.

(b) Contracts which terminate with fabrication and delivery shall include the preparation of field riveting and bolting lists and the furnishing of field rivets and permanent field bolts. The number furnished shall be the nominal number required, plus 15 percent (but not less than 10 extra) for each size and length. Such contracts shall not include the furnishing of fitting-up bolts, guys or other temporary parts or devices.

2. Plans

(a) Bidders shall submit proposals conforming to the terms of the letter of invitation. The proposals preferably shall be based on plans furnished by the Railroad Company. Such plans will show the dimensions of the building, floor levels, column centers, clearances, loads, sections of members and typical details.

(b) If the invitation requires the Contractor to furnish the design for the structural steel and iron work, he will be provided with general plans showing dimensions of the building, floor levels, column centers, clearances and loads. His design shall be based on the information furnished him and shall conform with these specifications. He shall submit, with his proposal, plans showing stresses, sections and dimensions of members, and typical details.

(c) The plans shall show a complete design with sizes, sections, and the relative location of the various members. Floor levels, column centers and off-sets shall be dimensioned. Plans shall be drawn to a scale large enough to convey the information adequately.

B. Material

3. Material

(a) Structural steel shall be made by the open-hearth process and shall conform to the Standard Specifications of the American Society for Testing Materials, Serial Designation A–7, as amended to date.

(b) Rivet steel shall conform to the Standard Specifications of the American Society for Testing Materials for Structural Rivet Steel, Serial Designation A–141, as amended to date.

(c) Cast steel shall conform to the Standard Specifications of the American Society for Testing Materials for Annealed Steel Castings, Grade B–1, Serial Designation A–27, as amended to date.

(d) Cast iron shall conform to the Standard Specifications of the American Society for Testing Materials for Gray-iron Castings, Serial Designation A–48, Class No. 25, as amended to date.

(e) Cast iron columns shall not be used in buildings of a height greater than 2 stories above the ground.

(f) The use of stock material may be permitted, but only after mill reports have been submitted to the Engineer and approved by him.

(g) Unidentified stock material, if free from surface imperfections, may be used for short sections of minor importance or for small unimportant details, where the precise physical properties of the material would not affect the strength of the structure.

C. Loads and Forces

4. Loads and Forces

(a) All structures shall be proportioned for the following loads and forces:

1. Dead load.
2. Live or superimposed load.
3. Wind load.
4. Lateral forces and longitudinal forces from moving loads.
5. Impact or dynamic effect of moving loads.

(b) The dead load shall consist of the estimated weight of all permanent portions of the structure, including partitions, permanent fixtures, mechanisms, etc.

(c) The live or superimposed load, snow and wind loads, lateral and longitudinal forces and impact will be specified by the Engineer for each case. (See Appendix A for typical loading.)

(d) The effect of any vibration or movement of machinery or equipment shall be specified for each case by the Engineer. (See Appendix A for typical loading.)

(e) Where uniform live loads per square foot are used for the roof and floors of a building, the roof slabs, joists, beams, girders and columns supporting them and all floor slabs, joists and beams shall be designed for full dead and full live loads. In structures designed for storage purposes, floor girders, columns, piers, walls, and foundations shall be designed for full dead and full live loads. In the design of all other structures, floor girders shall be designed for full dead and 85 percent of live loads and all columns, walls and piers supporting floors shall be designed for full dead load and the percentages of the live loads given in the following table:

Floor	*Number of Floors in Building*														
No.	*15*	*14*	*13*	*12*	*11*	*10*	*9*	*8*	*7*	*6*	*5*	*4*	*3*	*2*	*1*
15	85														
14	80	85													
13	75	80	85												
12	70	75	80	85											
11	65	70	75	80	85										
10	60	65	70	75	80	85									
9	55	60	65	70	75	80	85								
8	50	55	60	65	70	75	80	85							
7	50	50	55	60	65	70	75	80	85						
6	50	50	50	55	60	65	70	75	80	85					
5	50	50	50	50	55	60	65	70	75	80	85				
4	50	50	50	50	50	55	60	65	70	75	80	85			
3	50	50	50	50	50	50	55	60	65	70	75	80	85		
2	50	50	50	50	50	50	50	55	60	65	70	75	80	85	
1	50	50	50	50	50	50	50	50	55	60	65	70	75	80	85

The percentage of live load on walls, piers and columns of buildings more than 15 stories in height shall be taken in the same ratio as the above mentioned table.

The loads of special equipment, such as trucks, engines, cranes, machinery or other appliances, shall be included.

(f) Proper provisions shall be made for temporary stresses caused by erection.

(g) Structures in localities subject to earthquakes, hurricanes and extraordinary conditions shall be designed with due regard for such conditions.

5. Reversal of Stresses

Members subject to live loads producing alternating tensile and compressive stresses shall be proportioned as follows:

> To the net total compressive and tensile stresses add 50 percent of the smaller of the two and proportion the number to resist either of the increased stresses resulting therefrom. Connections shall be proportioned to resist the larger of the two increased stresses.

6. Combined Stresses

(a) Members subject to both axial and bending stresses shall be so proportioned that the quantity

$\frac{f_a}{F_a} + \frac{f_b}{F_b}$ shall not exceed unity, in which

F_a = axial unit stress that would be permitted by these specifications if axial stress only existed.

F_b = bending unit stress that would be permitted by these specifications if bending stress only existed.

f_a = axial unit stress (actual) = axial stress divided by area of member.

f_b = bending unit stress (actual) = bending moment divided by section modulus of member.

(b) Rivets subject to shearing and tensile forces shall be so proportioned that the combined unit stress will not exceed the allowable unit stress for rivets in tension only.

(c) In the design of structures having an assumed wind load of not less than 15 pounds per square foot of superficial area, the members subject to stresses produced by a combination of wind and other loads may be proportioned for unit stresses 33⅓ percent greater than those specified in Part D of the specifications, provided the section thus required is not less than that required for the combination of dead load, live load and impact (if any).

7. Members Carrying Wind Only

In the design of structures having an assumed wind load of not less than 15 pounds per square foot of superficial area, the members subject only to stresses produced by wind loads may be proportioned for unit stresses 33⅓ percent greater than those specified in Part D of these specifications.

8. Composite Beams

(a) The term "composite beam" shall apply to any steel beam entirely encased in a poured concrete encasement at least 4 inches wider, at its narrowest point, than the flange of the beam, supporting a concrete slab on each side without openings adjacent to the beam; provided that the top of the beam is at least 1½ inches below the top of the slab and at least 2 inches above the bottom of the slab; provided that the concrete conforms to Section IV "Concrete"; and provided that the concrete encasement has adequate mesh, or other reinforcing steel, throughout its whole depth and across the soffit.

(b) Composite beams may be figured on the assumptions that—

(1) The steel beam carries unassisted all dead loads prior to the hardening of the concrete, with due regard for any temporary support provided.

(2) The steel and concrete carry by joint action all loads, dead and live, applied after the hardening of the concrete.

(c) The total tensile unit stress in the extreme fiber of the steel beam thus computed shall not exceed 20,000 pounds per square inch, Part D of these specifications.

(d) The maximum stresses in the concrete and the ratio of Young's moduli for steel and concrete shall be as prescribed by the specifications governing the design of reinforced concrete for the structure.

(e) The web and the end connections of the steel beam shall be adequate to carry the total dead and live load without exceeding the unit stresses prescribed in these specifications, except as these may be reduced by the provision of other proper support.

9. Effective Span Length

(a) Beams, girders and trusses shall ordinarily be designed on the basis of simple spans, whose effective length is equal to the distance between centers of gravity of the members to which they deliver their end reactions.

(b) When designed on the assumption of end restraint, full or partial, based on continuous or cantilever action, beams, girders, trusses and their sections, as well as the sections of the members to which they connect, shall be designed to carry the shears and moments so introduced, in addition to all other forces, without exceeding at any point the unit stresses prescribed in Part D of these specifications.

10. Members Carrying Railway Tracks

Members subject to stresses produced by locomotives and cars shall be designed in accordance with the standard specifications of the American Railway Engineering Association for Steel Railway Bridges, except impact shall be 33 percent for restricted speeds.

11. Members Carrying Driveways

Members subject to stresses produced by vehicular traffic shall be designed in accordance with the standard specifications of the American Railway Engineering Association for Steel Highway Bridges.

D. UNIT STRESSES

12. Allowable Unit Stresses

All parts of the structure shall be so proportioned that the unit stresses in pounds per square inch shall not exceed the following values:

(a) Structural and Rivet Steel

Tension	
Structural steel, net section	20,000
Rivets, area based on nominal diameter	15,000
Hangers, rods and bolts, not upset for thread, net section	15,000
Hangers, rods and bolts, upset for thread, net section	20,000
Compression	
Columns, gross section	
For axially loaded columns with values of l/r not greater than 120	$17{,}000-0.485\frac{l^2}{r^2}$

For axially loaded columns with values of l/r greater than 120	$\frac{18{,}000}{1+\frac{l^2}{18{,}000r^2}}$
in which l is the unbraced length of the column and r is the corresponding radius of gyration of the section, both in inches. (For working stresses, see Appendix "C".)	
Plate girder stiffeners, gross section	20,000
Webs of rolled sections at toe of fillet (Crippling, see Article 22 (n))	24,000
Bending	
Tension on extreme fibers of rolled sections, plate girders and built-up members (See Article 22 (a))	20,000
Compression on extreme fibers of rolled sections, plate girders and built-up members, for values of l/b not greater than 40	$\frac{22{,}500}{1+\frac{l^2}{1{,}800b^2}}$
with a maximum of	20,000
in which l is the laterally unsupported length of the member and b is the width of the compression flange, both in inches.	
Stress on extreme fibers of pins	30,000
Shearing	
Rivets	15,000
Pins and turned bolts in reamed or drilled holes	15,000
Unfinished bolts	10,000
Webs of beams and plate girders, gross section	13,000

Bearing	*Double Shear*	*Single Shear*
Rivets	40,000	32,000
Turned bolts in reamed or drilled holes	40,000	32,000
Unfinished bolts	25,000	20,000
Pins	32,000	
Contact Area		
Milled stiffeners and other milled surfaces	30,000	
Fitted stiffeners	27,000	
Expansion Rollers and Rockers		
(pounds per linear inch) in which d is the diameter of roller or rocker in inches	$600d$	

(b) Cast Steel

Compression and bearing same as for structural steel. Other unit stresses 75 percent of those for structural steel.

(c) Cast Iron

Axial compression, gross section	12,000
Tension, extreme fiber in bending, net section	3,000
Compression, extreme fiber in bending, gross section	12,000
Shear	3,000
Axial compression, columns, gross section	$12{,}000-60\frac{l}{r}$
with a maximum of	10,000

(d) Masonry (Bearing)

Granite	800
Sandstone and limestone	400
Concrete, unless otherwise specified	600
Brickwork	200
Rubble masonry	100

The above unit stresses are based on masonry which shall comply with the standard specifications as set forth in other sections of these specifications for railway buildings.

E. Design

13. Slenderness Ratio

The ratio of unbraced length to least radius of gyration (l/r) shall not exceed:

For main compression members	120
For bracing and other secondary members in compression	200
For cast iron columns	100
For riveted tension members	300

14. Depth Ratios

The depth of rolled beams in floors shall be not less than 1/24 of the span. Where floors are subject to shocks or vibrations, the depth of beams and girders preferably shall be not less than 1/20 of the span, or, if members of less depth are used, the sectional area shall be increased until the maximum deflections will not be greater than that of a beam with depth of 1/20 of the span. The depth of roof purlins preferably shall be not less than 1/24 of the span, and in no case less than 1/30 of the span. Beams and girders supporting plastered ceilings shall be so proportioned that the maximum deflection will not exceed 1/360 of the span.

15. Unsupported Compression Flanges

The ratio of unbraced length to width of flange (l/b) for compression flanges of rolled sections, plate girders, and built-up members subject to bending shall not exceed 40.

16. Minimum Thickness of Material

(a) The minimum thickness of steel except for linings, fillers, and the webs of rolled beams and channels, shall be:

For exterior construction	$\frac{5}{16}$ inch
For interior construction	$\frac{1}{4}$ inch

(These provisions do not apply to light structures, such as skylights, marquees, fire-escapes, light one-story buildings, or light miscellaneous steel work.)

Inside of engine houses, material less than $\frac{5}{16}$ inch thick shall not be used except for fillers.

(b) Gusset plates for trusses with end reactions greater than 35,000 pounds shall be not less than $\frac{3}{8}$ inch thick.

Webs of girders shall be not less than $\frac{5}{16}$ inch thick.

Sole plates or bed plates shall be not less than $\frac{1}{2}$ inch thick.

Anchor bolts preferably shall be not less than 1 inch in diameter.

(c) The widths of the outstanding legs of angles in compression (except where reinforced by plates) shall not exceed 12 times the thickness for girder flanges and 16 times the thickness of other members.

(d) In compression members consisting of segments connected by cover plates or lacing, or segments connected by webs, the thickness of the webs of the segments shall be not less than 1/32 of the unsupported distance between the nearest rivet lines, or the roots of the flanges in case of rolled sections. The thickness of the cover plates or webs connecting the segments shall be not less than 1/40 of the unsupported distance between the nearest lines of their connecting rivets, or the roots of their flanges in case of rolled sections.

(e) Provision shall be made for parts subject to corrosive agents, either by increasing the thickness of material or by effective protection.

17. Cross and Net Sections

(a) The gross section of a member at ony point shall be determined by summing the products of the thickness and the gross width of each element as measured normal to the axis of the member. The net section shall be determined by substituting for the gross width, the net width computed in accordance with paragraphs (c) to (g) of Article 17.

(b) Unless otherwise specified, tension members shall be designed on the basis of net section. Columns shall be designed on the basis of gross section. Beams and girders shall be designed in accordance with Article 22 (a).

(c) Sections shall be made symmetrical wherever practicable. The effective area of single angles in tension shall be assumed as the net area of the connected leg plus 50 percent of the area of the unconnected leg. Single angles connected by lug angles shall be considered as connected by one leg.

(d) In the case of a chain of holes extending across a part in any diagonal or zigzag line, the net width of the part shall be obtained by deducting from the gross width the sum of the diameters of all the holes in the chain, and adding, for each gage space in the chain, the quantity $\frac{S^2}{4g}$, where

$S =$ longitudinal spacing (pitch) in inches of any two successive holes.
$g =$ transverse spacing (gage) in inches of the same two holes.

The critical net section of the part is obtained from that chain which gives the least net width.

(e) For angles, the gross width shall be the sum of the widths of the legs less the thickness. The gage for holes in opposite legs shall be the sum of the gages from back of angle less the thickness.

(f) For splice members, the thickness considered shall be only that part of the thickness of the member which has been developed by rivets beyond the section considered.

(g) In computing net area, the diameter of a rivet hole shall be taken as ⅛ inch greater than the nominal diameter of the rivet.

(h) In pin-connected tension members, the net section across the pin hole, transverse to the axis of the member, shall be not less than 140 percent, and the net section beyond the pin hole, parallel with the axis of the member, not less than 100 percent, of the net section of the body of the member.

(i) In all pin-connected riveted members, the net width across the pin hole, transverse to the axis of the member, shall preferably not exceed 8 times the thickness of the member at the pin.

18. Expansion

(a) No provision for transverse expansion in structures shall be made in wall bearing spans 50 feet and under in length. Wall bearing spans over 50 feet and up to and including 100 feet in length shall slide on smooth surfaces at one end. Wall bearing spans over 100 feet in length shall have expansion rollers or rockers at one end. Expansion rollers shall be not less than 3 inches in diameter. Expansion ends shall be secured against lateral movement and all fixed ends against movement in any direction.

(b) Provision shall be made for longitudinal expansion in structures. All expansion provisions shall be figured for 100 degrees F. variation in temperature and for a coefficient of expansion of 0.0000065 per degree per unit of length. Expansion joints shall not be more than 200 feet apart for buildings having masonry wall enclosures.

19. Connections

(a) Connections carrying calculated stresses, except for lacing, sag bars, and girts, shall have not less than 2 rivets.

(b) Members meeting at a point shall have their gravity axes meet at a point if practicable; if not, provision shall be made for their eccentricity.

(c) The rivets at the ends of any member transmitting stresses into that member should preferably have their centers of gravity on the gravity axis of the member; otherwise, provision shall be made for the effect of the resulting eccentricity. Pins may be so placed as to counteract the effect of bending due to dead load.

(d) When beams, girders or trusses are designed on the basis of simple spans in accordance with Article 9 (a), their end connections may ordinarily be designed for the reaction shears only. If, however, the eccentricity of the connection is excessive, provision shall be made for the resulting moment.

(e) When beams, girders or trusses are subject both to reaction shear and end moment, due to the restraint specified in Article 9 (b), their connections shall be specially designed to carry both shear and moment without exceeding at any point the unit stresses prescribed in Article 12. Ordinary end connections comprising only a pair of web angles, with not more than a nominal seat and top angle, shall not be assumed to provide for this kind of end moment.

(f) In truss construction when rivets carrying computed stresses pass through fillers, the fillers shall be extended beyond the connected member and the extension secured by sufficient rivets to develop the stress in the filler.

(g) Fillers under plate girder stiffeners at end bearings or points of concentrated loads shall be secured by sufficient rivets to prevent excessive bending and bearing stresses.

(h) Compression members when faced for bearing shall be spliced sufficiently to hold the connecting members accurately in place. Other joints in riveted work, whether in tension or compression, shall be spliced so as to transfer the stress to which the member is subject.

20. Rivets and Bolts

(a) In proportioning and spacing rivets, the nominal diameter of the undriven rivet shall be used.

(b) The effective bearing area of pins, bolts, and rivets shall be the diameter multiplied by the length in bearing; except that for countersunk rivets, half the countersunk depth shall be deducted.

(c) Rivets carrying calculated stress, and whose grip exceeds 5 diameters, shall have their number increased 1 percent for each additional 1/16 inch in the rivet grip. Special care shall be used in heating and driving such rivets.

(d) Rivets shall be used for the following connections:

Connections for supports of running machinery, or of other live loads which produce impact or reversal of stress.

Roof-truss splices and connections of trusses to columns, column splices, column bracing, and crane supports, in all structures carrying cranes of over 5-ton capacity.

Column splices in all tier structures 200 feet or more in height.

Column splices in tier structures 100 to 200 feet in height, if the least horizontal dimension is less than 40 percent of the height.

Column splices in tier structures less than 100 feet in height, if the least horizontal dimension is less than 25 percent of the height.

Connections of all beams and girders to columns, and of any other beams and girders on which the bracing of columns is dependent, in structures over 125 feet in height. (For the purpose of this specification, the height of a tier structure shall be taken as the vertical distance from the curb level to the highest point of the roof beams in the case of flat roofs, or to the mean height of the gable in the case of roofs having a rise of more than 1 to a 4½ run. Where the curb level has not been established, or where the structure does not adjoin a street, the mean level of the adjoining land shall be used instead of curb level. Penthouses may be excluded in computing the height of a structure).

Any other connections stipulated on the design plans.

(e) Field connections may be made with unfinished bolts, except as provided in Article 20 (d).

(f) Turned bolts in reamed or drilled holes, as specified in Article 29 (e), may be used in shop or field work where it is impossible to drive satisfactory rivets. The finished shank shall be long enough to provide full bearing, and washers shall be used under the nuts to give full grip when the nuts are turned tight.

(g) The end reaction stresses of trusses, girders, or beams, and the axial stresses of tension or compression members which are carried on rivets or bolts, shall have such stresses developed by the shearing and bearing values of the rivets or bolts.

21. Rivet Spacing

(a) The minimum distance between centers of rivet holes shall be 3 diameters of the rivet; but the distance shall preferably be not less than 4½ inches for 1¼-inch rivets, 4 inches for 1⅛-inch rivets, 3½ inches for 1-inch rivets, 3 inches for ⅞-inch rivets, 2½ inches for ¾-inch rivets, 2 inches for ⅝-inch rivets, and 1¾ inches for ½-inch rivets.

(b) The maximum pitch in the line of stress of compression members composed of plates and shapes shall not exceed 16 times the thickness of the thinnest outside plate or shape, nor 20 times the thinnest enclosed plate or shape with a maximum of 12 inches, and at right angle to the direction of stress the distance between lines of rivets shall not exceed 30 times the thickness of the thinnest plate or shape. For angles in built sections with 2 gage lines, with rivets staggered, the maximum pitch in the line of stress in each gage line shall not exceed 24 times the thickness of the thinnest plate with a maximum of 18 inches.

(c) The pitch of rivets at the ends of built compression members shall not exceed 4 diameters of the rivets for a length equal to 1½ times the maximum width of the member.

(d) In tension members composed of two angles, a pitch of 3 feet 6 inches will be allowed, and in compression members, 2 feet, but the ratio l/r for each angle between rivets shall be not more than ¾ of that for the whole member.

(e) The minimum distance from the center of any punched rivet hole to any edge shall be that given in Table 1.

TABLE 1

Minimum Edge Distance (inches) for Punched Holes

Rivet Diameter Inches	*In Sheared Edge*	*In Rolled Edge of Plates and Sections with Parallel Flanges*	*In Rolled Edge of Sections with Sloping Flanges*
½	1	⅞	¾*
⅝	1⅛	1	⅞*
¾	1¼	1⅛	1*
⅞	1½	1¼	1⅛*
1	1¾	1½	1¼*
1⅛	2	1¾	1½*
1¼	2¼	2	1¾*

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* May be decreased ⅛ inch when holes are near end of beam.

(f) The distance from the center of any rivet under computed stress, and that end or other boundary of the connected member toward which the pressure of the rivet is directed, shall be not less than the shearing area of the rivet shank (single or double shear respectively) divided by the plate thickness. This end distance may however be decreased in such proportion as the stress per rivet is less than that permitted under Article 12 (a); and the requirement may be disregarded in case the rivet in question is one of three or more in a line parallel to the direction of stress.

(g) The maximum distance from the center of any rivet to the near edge shall be 12 times the thickness of the plate, but shall not exceed 6 inches.

22. Plate Girders and Rolled Beams

(a) Riveted plate girders, cover-plated beams, and rolled beams shall in general be proportioned by the moment of inertia of the gross section. No deduction shall be made for standard shop or field rivet holes in either flange; except where the reduction of the area of either flange by such rivet holes, calculated in accordance with the provisions of Article 17, exceeds 15 percent of the gross flange area, the excess shall be deducted. If such members contain other holes, as for bolts, pins, or countersunk rivets, the full deduction for such holes shall be made. The deductions thus applicable to either flange shall be made also for the opposite flange if the corresponding holes are there present.

(b) Plate girder webs shall have a thickness of not less than 1/170 of the unsupported distance between flanges.

(c) Cover plates, when required, shall be equal in thickness or shall diminish in thickness from the flange angles outward. No plate shall be thicker than the flange angles.

(d) Unstiffened cover plates shall not extend more than 6 inches nor more than 12 times the thickness of the thinnest plate beyond the outer row of rivets connecting them to the angles. The total cross sectional area of cover plates shall not exceed 70 percent of the total flange area.

(e) Rivets connecting the flanges to the web shall be proportioned to resist the horizontal shear due to bending as well as any loads applied directly to the flange.

(f) Stiffeners shall be placed on the webs of plate girders at the ends and at points of concentrated loads. Such stiffeners shall have a close bearing against the flanges, shall extend as closely as possible to the edge of the flange angles, and shall not be crimped. They shall be connected to the web by enough rivets to transmit the stress. Only that portion of the outstanding legs outside of the fillets of the flange angles shall be considered effective in bearing.

(g) If h/t is equal to or greater than 70, intermediate stiffeners shall be required at all points where h/t exceeds $\frac{8,000}{\sqrt{s}}$, in which

h = the clear depth between flanges, in inches
t = the thickness of the web, in inches
s = greatest unit sheear in panel, in pounds per square inch under any condition of complete or partial loading.

(h) The clear distance between intermediate stiffeners, when stiffeners are required by the foregoing, shall not exceed 84 inches or that given by the formula

$$d = \frac{270,000t^3}{s} \sqrt{\frac{st}{h}}$$

d = the clear distance between stiffeners, in inches.

(i) Intermediate stiffeners may be crimped over the flange angles.

(j) Plate girder stiffeners shall be in pairs, one on each side of the web, and shall be connected to the web by rivets spaced not more than 8 times their nominal diameter.

(k) Web splices in plate girders shall be proportioned to transmit the full shearing and bending stresses in the web at the point of splice.

(l) Flange splices shall be proportioned to develop the full stress of the members cut.

(m) The flanges of plate girders supporting cranes or other moving loads shall be proportioned to resist any lateral forces produced by such loads.

(n) Rolled beams shall be so proportioned that the compression stress at the web toe of the fillets, resulting from concentrated loads, shall not exceed the value of 24,000 pounds per square inch allowed in Article 12 (a). The governing formulas shall be:

For interior loads $\frac{R}{t\,(N+2k)}$ not over 24,000

For end reactions $\frac{R}{t\,(N+k)}$ not over 24,000

R = concentrated interior load or end reactions, in pounds.
t = thickness of web, in inches.
N = length of bearing, in inches.
k = distance from outer face of flange to web toe of fillet, in inches.

23. Separators

Where 2 or more rolled beams are used to form a girder, they shall be connected by bolts and separators at intervals of not more than 5 feet. All beams having a depth of 12 inches or more shall have at least 2 bolts to each separator. When concentrated loads are carried from one beam to the other, or distributed between the beams, rolled or built-up diaphragms shall be used, designed with sufficient stiffness to distribute the load. Where beams are exposed, they shall be filled with concrete or spaced sufficiently far apart to permit cleaning and painting.

24. Tie Plates

(a) The open sides of compression members shall be provided with lacing having tie plates at each end, and at intermediate points if the lacing is interrupted. Tie plates shall be as near the ends as practicable. In main members carrying calculated stresses, the end tie plates shall have a length of not less than the distance between the lines of rivets connecting them to the segments of the member, and the intermediate plates a length of not less than one-half of this distance. The thickness of tie plates shall be not less than 1/50 of the distance between the lines of rivets connecting them to the segments of the members, and the rivet pitch shall be not more than 4 diameters. Tie plates shall be connected to each segment by at least 3 rivets.

(b) Tie plates shall be used to secure the parts of tension members composed of shapes. They shall have a length not less than ⅔ of the length specified for tie plates in compression members. The thickness shall be not less than 1/50 of the distance between the lines of rivets connecting them to the segments of the member and they shall be connected to each segment by at least 3 rivets.

25. Lacing

(a) Lacing bars of compression members shall be so spaced that the ratio l/r of the flange included between their connections shall be not over ¾ of that of the member as a whole.

(b) Lacing bars shall be proportioned to resist a shearing stress normal to the axis of the member equal to 2 percent of the total compressive stress in the member. In determining the section required, the compression formula shall be used, l being taken as the length of the bar between the outside rivets connecting it to the segment for single lacing and 70 percent of that distance for double lacing. The ratio l/r shall not exceed 140 for single lacing nor 200 for double lacing.

(c) The thickness of lacing bars shall be not less than 1/40 for single lacing, and 1/60 for double lacing, of the distance between end rivets; their minimum width shall be 3 times the diameter of the rivets connecting them to the segments.

(d) The inclination of lacing bars to the axis of the members shall preferably be not less than 45 degrees for double lacing and 60 degrees for single lacing. When the distance between the rivet lines in the flanges is more than 15 inches, the lacing shall be double and riveted at the intersection if bars are used, or else shall be made of angles.

26. Adjustable Members

The total initial stress in an adjustable member shall be assumed as not less than 5,000 pounds.

27. Column Bases

(a) Proper provision shall be made to transfer the column loads, and moments if any, to the footings and foundations.

(b) Column bases shall be set level and to correct elevation with full bearing on the masonry.

(c) Column bases shall be finished to conform with the following requirements:

1. Rolled steel bearing plates, 2 inches or less in thickness, may be used without planing, provided a satisfactory contact bearing is obtained; rolled steel bearing plates, over 2 inches, but 4 inches or less in thickness, may be straightened by pressing (planed on all bearing surfaces if presses are not available) to obtain a satisfactory contact bearing; rolled steel bearing plates, over 4 inches in thickness, shall be planed on all bearing surfaces (except as noted under 3).
2. Column bases other than rolled steel bearing plates shall be planed on all bearing surfaces (except as noted under 3).
3. The bottom surfaces of bearing plates and column bases which rest on masonry foundations and are grouted to insure full bearing contact need not be planed.

28. Anchor Bolts

Anchor bolts shall be of sufficient size and number to develop the computed stress

F. FABRICATION

29. Workmanship

(a) All workmanship shall be equal to the best practice in modern structural shops.

(b) All material shall be clean and straight. If straightening or flattening is necessary, it shall be done by a process and in a manner that will not injure the material. Sharp kinks or bends shall be cause for rejection.

(c) Rolled sections, except for minor details, shall preferably not be heated or, if heated, shall be annealed, but this restriction does not apply to gas cutting, Article 29 (q).

(d) Holes for rivets or unfinished bolts shall be 1/16 inch larger than the nominal diameter of the rivet or bolt. If the thickness of the material is not greater than the nominal diameter of the rivet or bolt plus ⅛ inch, the holes may be punched. If the thickness of the material is greater than the nominal diameter of the rivet or bolt plus ⅛ inch, the holes shall be either drilled from the solid, or sub-punched and reamed. The die for all sub-punched holes, and the drill for all sub-drilled holes, shall be 1/16 inch smaller than the nominal diameter of the rivet or bolt.

(e) Holes for turned bolts shall be 1/50 inch larger than the external diameter of the bolt. If the bolts are to be inserted in the shop, the holes may be either drilled from the solid, or sub-punched and reamed. If the bolts are to be inserted in the field, the holes shall be sub-punched in the shop and reamed in the field. All drilling or reaming for turned bolts shall be done after the parts to be connected are assembled.

(f) Drifting to enlarge unfair holes shall not be permitted. Holes that must be enlarged to admit the rivets shall be reamed. Poor matching of holes shall be cause for rejection.

(g) Planing or finishing of sheared plates or shapes will not be required unless specifically called for on the drawings.

(h) All parts of riveted members shall be well pinned or bolted and rigidly held together while riveting. Drifting done during assembling shall not distort the metal or enlarge the holes.

(i) All rivets are to be power-driven hot. Rivets driven by pneumatically or electrically operated hammers are considered power-driven. Standard rivet heads shall be of approximately hemispherical shape and of uniform size throughout the work for the same size rivet, full, neatly finished, and concentric with the holes. Rivets, after driving, shall be tight, completely filling the holes, and with heads in full contact with the surface. Rivets shall be heated uniformly to a temperature not exceeding 1950 degrees F.; they shall not be driven after their temperature is below 1000 degrees F. Loose, burned, or otherwise defective rivets shall be replaced.

(j) Compression joints depending upon contact bearing shall have the bearing surfaces truly machined to a common plane after the members are riveted. All other joints shall be cut straight.

(k) The ends of lacing bars shall be neat and free from burrs.

(l) Finished members shall be true to line and free from twists, bends, and open joints.

(m) Compression members may have a lateral variation not greater than 1/1000 of the axial length between points which are to be laterally supported.

(n) A variation of 1/32 inch is permissible in the overall length of members with both ends milled.

(o) Members without milled ends which are to be framed to other steel parts of the structure may have a variation from the detailed length not greater than 1/16 inch for members 30 feet or less in length, and not greater than ⅛ inch for members over 30 feet in length.

(p) All steel castings shall be annealed.

(q) The use of a cutting torch is permissible if the metal being cut is not carrying stresses during the operation. To determine the effective width of members so cut, ⅛ inch shall be deducted from each gas cut edge. The radius of re-entrant gas cut fillets shall be as large as practicable, but never less than 1 inch.

(r) Steel shall be welded only with the approval of the Engineer.

30. Camber

Trusses shall have sufficient camber so that the lower chord will be level under dead load only.

31. Shop Painting

(a) Before leaving the shop, all steelwork shall be thoroughly cleaned, by effective means, of all loose mill scale, rust and foreign matter. Except where encased in concrete, or otherwise called for on drawings, all steel work shall be given 1 coat of approved metal protection, applied thoroughly and evenly and well worked into the joints and other open spaces. All paint shall be applied to dry surfaces.

(b) Parts inaccessible after assembly shall be given 2 coats of shop paint, preferably of different colors.

(c) Contact surfaces shall be cleaned, by effective means, before assembly, but not painted.

(d) Machine-finished surfaces shall be protected against corrosion by a suitable coating.

(e) Erection marks shall be painted on the members. The weight shall be marked on members weighing more than 5 tons.

G. INSPECTION

32. Inspection

(a) Material and workmanship at all times shall be subject to the inspection of experienced engineers representing the purchaser.

(b) All inspection as far as possible shall be made at the place of manufacture, and the Contractor or Manufacturer shall co-operate with the Inspector, permitting access for inspection to all places where work is being done.

(c) Material or workmanship not conforming to the provisions of these specifications may be rejected at any time defects are found during the progress of the work.

H. WEIGHING AND SHIPPING

33. Weight Paid For

The payment in pound price contracts shall be based on the weight of the metal in the fabricated structure. Either scale weights or computed weights may be used. The weight of field paint and cement, boxes and barrels used for packing, and material used for staying or supporting members on cars, shall not be included.

34. Variation in Weights

(a) If the scale weight of any member is less than 97½ percent of the computed weight, it shall be cause for rejection.

(b) The greatest allowable variation of the total scale weight of any structure from the weights computed from the approved shop drawings shall be 1½ percent. Any weight in excess of 1½ percent above the computed weight will not be paid for.

35. Computed Weight

(a) The weight of steel shall be assumed at 0.2833 pound per cubic inch.

(b) The weight of cast iron shall be assumed at 0.2604 pound per cubic inch.

(c) The weights of rolled shapes and of plates, up to and including 36 inches in width, shall be computed on the basis of their nominal weights and dimensions as shown on the approved shop drawings, deducting for copes, cuts and open holes.

(d) The weights of plates wider than 36 inches shall be computed on the basis of their dimensions, as shown on the approved shop drawings, deducting for cuts and open holes. To this shall be added ½ of the allowed percentages of over-run in weight given in specifications of the American Society for Testing Materials.

(e) The weight of heads of shop driven rivets shall be included in the computed weight.

(f) The weights of castings shall be computed from the dimensions shown on the approved shop drawings with an addition of 10 percent for fillets and over-runs.

36. Weights of Members

Finished work shall be weighed in the presence of the Inspector, if practicable. The Contractor shall furnish satisfactory scales and do the handling of the material for weighing.

37. Gross Weight Payment

In lieu of the provisions of Articles 33 to 36 inclusive, when so stipulated in the invitation to bid, the payment for pound-price contracts may be based on the gross weight as computed in accordance with Section 3 (a) of the Code of Standard Practice of the American Institute of Steel Construction.

38. Marking and Shipping

(a) Members weighing more than 5 tons shall have the weight marked thereon. Bolts and rivets of one length and diameter, and loose nuts or washers of each size, shall be packed separately. Pins, other small parts, and small packages of bolts, rivets, washers and nuts shall be shipped in boxes, crates, kegs or barrels, but the gross weight of any package shall not exceed 300 pounds. A list and description of the contained material shall be plainly marked on the outside of each package, box or crate.

(b) Anchor bolts, washers and other anchorage or grillage materials shall be shipped in time for them to be built into the masonry.

I. ERECTION

39. General

The Contractor for erection shall provide all tools, machinery, equipment and erection material, including drift pins and fitting up bolts, necessary for the expeditious handling of the work, and shall erect the structural steel and iron work complete in every respect as covered by the agreement and in accordance with the drawings and these specifications.

40. Drawings

Where the fabricated material is furnished by others, the Company will furnish complete detail drawings for the work, including shop details, erection diagrams, match marking diagrams, lists of field rivets and bolts, and copies of shipping statements.

41. Delivery of Material

The Contractor for Erection shall receive all materials entering into the finished structure free of charge at the place designated, loaded or unloaded as specified in the information given bidders.

42. Handling and Storage of Materials

The Contractor shall unload material promptly upon delivery, otherwise he shall be responsible for demurrage charges. Stored material shall be piled securely outside away from the tracks and no material shall be placed closer than 6 feet to the near rail. Material shall be placed on skids, above the ground. It shall be kept clean and properly drained. Girders and beams shall be placed upright and when necessary shall be shored. Long members, such as columns and chords. shall be supported on skids placed near enough together to prevent injury from deflection. The Contractor shall check all material turned over to him against shipping lists and report in writing at once any shortage or injury discovered. He will be held responsible for the loss of any material while in his care or for any damage resulting from his work.

43. Masonry

The Company will construct the masonry to correct lines and elevations and will establish the lines and elevations required by the Contractor for setting the steel.

44. Bearings and Anchorage

(a) Bed plates, bolsters and shoes shall be set level in exact position. They shall be given full and even bearing by setting them on a layer of Portland cement mortar after blocking them accurately in position as directed by the Engineer.

(b) The Contractor shall drill the holes and set the anchor bolts, except where the bolts are built into the masonry. The bolts shall be set accurately and fixed with Portland cement grout completely filling the holes.

45. Methods and Equipment

Before starting work, the Contractor shall advise the Engineer fully as to the method he proposes to follow, and the amount and character of equipment he proposes to use, which shall be subject to the approval of the Engineer. The approval of the Engineer shall not be considered as relieving the Contractor of the responsibility for the safety of his method or equipment, or from carrying out the work in full accordance with drawings and specifications.

46. Workmanship

(a) The frame of all steel skeleton buildings shall be carried up true and plumb, and temporary bracing shall be introduced wherever necessary to take care of all loads to which the structure may be subjected, including erection equipment, and the operation of same. Such bracing shall be left in place as long as may be required for safety.

(b) As erection progresses, the work shall be securely bolted up to take care of all dead load, wind and erection stresses.

(c) Wherever piles of material, erection equipment or other loads are carried during erection, proper provision shall be made to take care of stresses resulting from the same.

(d) No riveting shall be done until the structure has been properly alined.

(e) Rivets driven in the field shall be heated and driven with the same care as those driven in the shop.

(f) Holes for turned bolts to be inserted in the field shall be reamed in the field as specified in Article 29 (e).

(g) All field rivets and bolts, also all serious abrasions to the shop coat, shall be spot painted with the material used for the shop coat, or an equivalent, and all mud and other firmly attached and objectionable foreign materials shall be removed before general field painting. Unless otherwise specified, general field painting is not included under this heading.

47. Misfits

Any error in shop work which prevents the proper assembling and fitting up of parts shall immediately be reported to the inspector and his approval of the method of correction obtained.

48. Superintendence and Workmen

During the entire progress of the work, the Contractor shall have a competent foreman or superintendent in personal charge of the work. All work shall be done by skilled, competent workmen.

49. Interference With Traffic

When work is adjacent to or over the tracks of the Company, the Contractor shall conduct his work in such a manner that the track shall be safe and clear for the passage of trains.

50. General Conditions

(a) All materials entering into the work and all methods used by the Contractor shall be subject to the approval of the Engineer, and no part of the work will be considered as finally accepted until all of the work is completed.

(b) The General Conditions as given in Section I of these specifications shall be considered to apply with equal force to this section of the specifications.

Appendix A

The following weights of materials, live loads and impacts are given as information for use in designing:

1. Weights of Materials of Construction

The unit weights of some materials will vary according to locality, and the weights of some will vary because of a difference in quality. The following values may be used as averages for ordinary conditions:

	Pounds
Book tile, 2 inches thick, per square foot	12
Book tile, 3 inches thick, per square foot	14
Beam tile (when not included with arch tile), per square foot	12
Brick masonry, pressed or paving, per cubic foot	140
Brick masonry, hard common, per cubic foot	120
Brick masonry, hollow, per cubic foot	90
Cast iron, bar 1 inch square, per lineal foot	3.125
Cast iron, per cubic inch	26
Cinder concrete, per cubic foot	96
Cinder fill (without sand and cement), per cubic foot	72
Floors, marble, tutti colori, and similar, per square foot	12
Floor flat arch (average of set), 8 inches thick, per sq. ft.	28
Floor flat arch (average of set), 10 inches thick, per sq. ft.	32
Floor flat arch (average of set), 12 inches thick, per sq. ft.	36
Floor flat arch (average of set), 14 inches thick, per sq. ft.	40
Floor flat arch (average of set), 16 inches thick, per sq. ft.	46
Floor segmental arch tile (average of set), 6 inches thick at crown, per sq. ft.	28
Granite, per cubic foot	160
Gypsum partition blocks, 3 inches thick, per square foot	10
Gypsum partition blocks, 4 inches thick, per square foot	12
Gypsum partition blocks, 5 inches thick, per square foot	14
Gypsum partition blocks, 6 inches thick, per square foot	16
Marble, per cubic foot	175

	Pounds
Mortar and plaster, per cubic foot	120
Mortar for tile arch floors, per square foot	3
Oaks, maple, per foot board measure	5
Ornamental terra cotta, backed and filled with common brick, per cubic foot	120
Partition tile, 3 inches thick, per square foot	14
Partition tile, 4 inches thick, per square foot	15
Partition tile, 6 inches thick, per square foot	22
Partition tile, 8 inches thick, per square foot	28
Partition tile, 10 inches thick, per square foot	32
Plaster on brick, concrete, tile or gypsum	5
Plaster on lath, per square foot	7
Roofing, composition, per square foot	5
Roofing gravel, per square foot	10
Roofing slate, per square foot	10
Roofing tile, per square foot	10
Roofing, shingle, per square foot	3
Sandstone or limestone rubble, per cubic foot	140
Sandstone or limestone cut facing, per cubic foot	150
Sheet metal roofing, cornice, etc., per square foot	3
Suspended ceiling complete, per square foot	10
Steel bar, 1 inch square, per lineal foot	3.4
Steel plate, 1 inch thick, per square foot	40.8
Stone concrete, per cubic foot	144
Windows, (glass, frames and sash), per square foot	5
White pine, spruce, hemlock, per foot board measure	3
Yellow pine, fir, per foot board measure	4

The following items may vary considerably in weight but the values given may be used for preliminary computations, or when the quantities are small:

	Pounds
Concrete stair construction, per square foot	150
Iron stair construction, per square foot	50
Partition, 4 inch tile plastered, per square foot	25
Same in hotels, per square foot of floor	35
Same in office buildings, per square foot of floor	25
Reinforcement of concrete, per cubic foot	6
Sidewalk lights in concrete, per square foot	30
Steel joists, per square foot of floor	6
Steel girders, per square foot of floor	4
Total weight of reinforced concrete, per cubic foot	150
Wood stair construction, per square foot	20

Structure	*Loads in Pounds per Square Foot*
Roofs	25
Scale houses	50
Scrap docks	300
Sidewalks	100
Signal towers	60
Stables	100
Stairways (all)	100
Station foot bridges	100
Stock pens	100
Stock runways	100
Storehouses—	
Bananas—on racks	50
Beverages	350
Cement	450
Cotton	250
Flour	300

	Loads in Pounds per Square Foot
Fruits	350
Glass	350
Grain	300
Groceries and canned goods	350
Hay—baled	225
Hay—loose	125
Hardware	300
Oil	250
Paint	250
Railway	300
Salt	300
Soda ash	200
Vegetables	350
Telegraph offices	50
Ticket offices	50
Tool equipment buildings	100
Trainmen's rooms	50
Transfer platforms	150
Waiting rooms	100
Wash rooms	50
Water treating plants	100
Wind pressure	15 and 20
Y.M.C.A. buildings	50

2. Live Loads

The following live loads may be used in all cases except where they conflict with local building ordinances or with the known facts regarding the installation:

Structure	*Loads in Pounds per Square Foot*
Baggage rooms	150
Carpenter shops	150
Coaling platforms	Special
Commissaries	300
Cotton loading platforms	200 to 400
Express buildings	150
File rooms	100 to 150; 100 pounds for cases spaced over 4 feet clear; balance 150 pounds
Fire escapes	100
Freight houses	300
Freight platforms	300
Garages—Passenger Cars	75
—Trucks and Busses	175
Hospitals	50
Hotels—Guests' rooms	50
Lobbies	100
Halls	100
Assembly rooms	100
Storerooms	150
Ice Manufacturing Plants	150
Ice crusher houses	150
Ice storage	Special
Icing platforms	150
Laundries	100
Locker rooms	50
Machine shop—lightwork	100

	Loads in Pounds per Square Foot
Mail rooms	100
Offices and office buildings, General office space	50
Paint shop	100
Passenger platforms	100
Planing mills	150
Power houses	100
Reading rooms	50
Residences	40
Restaurants	50

3. Special Loads

In addition to the live load which is assumed to be uniformly distributed over the floor, provision shall be made for any special loads such as elevators, machinery, water in tanks, coal in bins, space for storage of special materials, etc. The weight of water is 62.5 pounds per cubic foot, or 8⅓ pounds per gallon; of bituminous coal, 50 pounds per cubic foot; of anthracite coal, 60 pounds per cubic foot.

The weights of elevators are usually given by the manufacturer for the particular situation.

4. Wind Load

Wind shall be assumed as acting horizontally from any direction and shall be provided for as follows:

(a) For Finished Structures: A pressure of 15 pounds per square foot on the sides and ends of the building, and on the vertical projection of roof surfaces.

(b) For Structures in Process of Construction: A pressure of 20 pounds per square foot on vertical surfaces and the vertical projection of inclined surfaces of all exposed framework.

5. Snow Load

Snow load shall be specified by the Engineer to suit local conditions. This load shall be considered a constant load on the horizontal projection of roofs from flat roof up to roof slope of 45 degrees, omitting snow load on roofs steeper than 45 degrees slope.

6. Lateral Force

The lateral force on crane runways to provide for the effect of crane trolleys shall be 20 percent of the moving load of the crane. This load shall be applied at the top of rail of crane runway, ½ the load to each side of runway, and considered as acting in either direction normal to the runway rail.

7. Longitudinal Force

In the design of crane runways, provision shall be made for a longitudinal force per rail equal to 10 percent of the wheel loads of the crane applied at top of rail on the runway.

8. Impact

Where live loads causing shock or vibrations are carried, the following shall be added to the computed live-load stress produced by such loads to provide for the dynamic effect of impact:

Character of load	*Impact Allowance percent of live-load stress*
Elevators	100
Traveling cranes	25
Stationary vibrating machines	20
Turbines	100

APPENDIX B

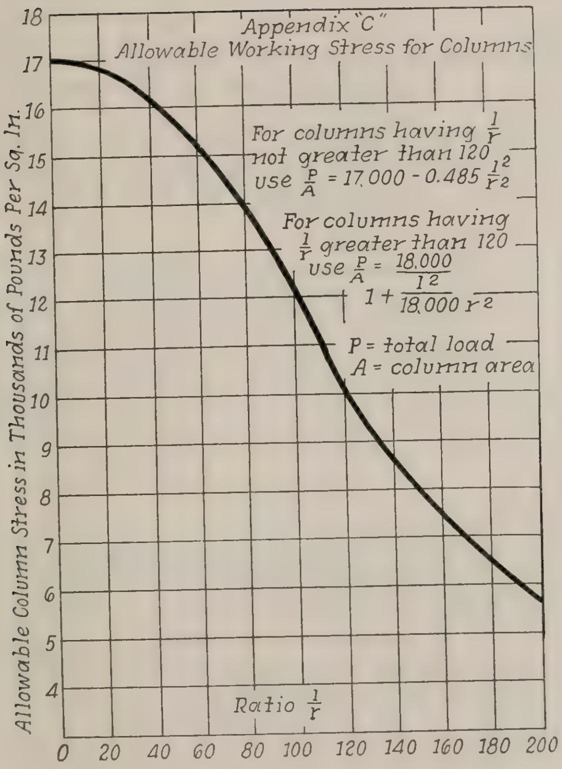
ALLOWABLE UNIT STRESSES

In Kips (1,000 pounds) per Square Inch for Beams and Girders Laterally Unsupported

$$f = \frac{22{,}500}{1 + \dfrac{l^2}{1{,}800b^2}}$$

$l =$ Unsupported length in inches
$b =$ Width of flange in inches

$\frac{l}{b}$	*Unit Stress* f	*Ratio*	$\frac{l}{b}$	*Unit Stress* f	*Ratio*	$\frac{l}{b}$	*Unit Stress* f	*Ratio*
15.0	20.00	1.000	23.5	17.22	.861	32.0	14.34	.717
15.5	19.85	.993	24.0	17.05	.852	32.5	14.18	.709
16.0	19.70	.985	24.5	16.87	.844	33.0	14.02	.701
16.5	19.54	.977	25.0	16.70	.835	33.5	13.86	.693
17.0	19.39	.969	25.5	16.53	.826	34.0	13.70	.685
17.5	19.23	.961	26.0	16.36	.818	34.5	13.54	.677
18.0	19.07	.953	26.5	16.19	.809	35.0	13.39	.669
18.5	18.91	.945	27.0	16.01	.801	35.5	13.23	.662
19.0	18.74	.937	27.5	15.84	.792	36.0	13.08	.654
19.5	18.58	.929	28.0	15.67	.784	36.5	12.93	.647
20.0	18.41	.920	28.5	15.50	.775	37.0	12.78	.639
20.5	18.24	.912	29.0	15.34	.767	37.5	12.63	.632
21.0	18.07	.904	29.5	15.17	.758	38.0	12.49	.624
21.5	17.90	.895	30.0	15.00	.750	38.5	12.34	.617
22.0	17.73	.887	30.5	14.84	.742	39.0	12.20	.610
22.5	17.56	.878	31.0	14.67	.733	39.5	12.05	.603
23.0	17.39	.869	31.5	14.50	.725	40.0	11.91	.596


Appendix "C"
Allowable Working Stress for Columns
For columns having $\frac{l}{r}$ not greater than 120 use $\frac{P}{A} = 17{,}000 - 0.485 \frac{l^2}{r^2}$
For columns having $\frac{l}{r}$ greater than 120 use $\frac{P}{A} = \frac{18{,}000}{1 + \frac{l^2}{18{,}000\, r^2}}$
P = total load
A = column area
Allowable Column Stress in Thousands of Pounds Per Sq. In.
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
Ratio $\frac{l}{r}$
0
20
40
60
80
100
120
140
160
180
200

Appendix B

(5) Drinking Water Facilities in Railway Buildings

Collaborating with Committee 13—Water Service, Fire Protection and Sanitation

H. C. Lorenz (chairman, subcommittee), A. C. Copland, H. G. Dalton, A. G. Dorland, A. T. Hawk, H. A. Pasman, Dr. E. W. Scripture, Jr.

Modern drinking water facilities may be classified as follows:

Portable Units

(a) *Iced Cooler.*—Consists usually of an inverted water bottle, mounted on iced container, equipped with a spigot, drip basin, etc., and so arranged that the water is not in contact with the ice.

(b) *Portable Mechanical Cooling Unit.*—Consists of an inverted water bottle or other container for holding the water supply, equipped with a spigot, drip basin, etc., mounted on a mechanical cooling unit. Capacity indicated in Table 1.

Fixed Units

(a) *Coils for Ice-Cooling Connected to Water Supply Line.*—May be obtained in a combination fixture, consisting of a cooler, equipped with one or more bubblers, or one or more spigots, or a combination of spigots and bubblers. The cooler consists of coils contained in an insulated tank, and a drain. This combination fixture may also be used where it is desired to conceal a cooler that is to serve several fountains elsewhere.

(b) *Mechanical Cooling Units Connected to Water Supply Line.*—This type consists of a cooling unit, equipped with bubblers or spigots, or both, and a waste drain. May be installed at places where it is desired to serve several fountains with one unit. Capacity indicated in Table 1.

Central System for Circulating Cooled Water

(a) *Ice Cooled.*—Consists of an insulated ice storage tank with water-cooling tank, water-cooling coils, or coil and tank, circulating pump, insulated water supply lines, fountain fixtures, and drains.

(b) *Mechanically Cooled.*—Consists of an insulated ice storage tank, circulating pump, mechanical cooling machine with necessary valves, electrical controls, insulated water supply and return lines and fountain fixtures.

Equipment Available

Iced coolers can be obtained to suit various requirements.

Table 1

Capacities of Mechanical Equipment Available

Capacity Gal. per Hr.	*Storage Gal.*	*Remarks*
1.5	0.5	Portable or fixed
3 to 5	0.5	Fixed
5 to 10	0.8	Fixed
10 to 20	3.0	Fixed
25	5.0	Fixed

The rating of a mechanical unit is usually based on its capacity for cooling water from 80 deg. to 50 deg. F., when operating in an 80-deg. F. room temperature.

TABLE 2

DRINKING WATER REQUIREMENTS RECOMMENDED BY THE NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION

Type of Service	*Delivered Water Temperature—Fahrenheit*	*Gallons per Person per Hour*	*Waste and Consumption per Person per Hour—Ounces*	*Consumption Only, per Person per Hour—Ounces*	*People Served per Gallon*
Offices (cup)	45–50	0.033	4.2	4.2	30
Offices (bubbler)	45–50	0.083	10.5	4.2	12
Light manufacturing	45–50	0.143	18.3	7.32	7
Heavy manufacturing	50–55	0.20	25.6	10.24	5
Hot heavy manufacturing	55–60	0.25	32.0	12.8	4
Restaurants	40–45	0.1 (per person)			
Cafeterias	40–45	0.083 (per person)			
Theatres (Movie)	45–50	1.0 (per 100 seats)			
Theatres (Legit.)	45–50	1.0 (per 100 seats continuous capacity)			
		Each fountain shall have storage capacity to provide 5 gal. in 10 min.			
Schools	45–50	Same as offices			
Hospitals:					
A. Per bed	45–50	0.083			
B. Per attendant	45–50	0.083			
Hotels	45–50	0.08 (per hour per room)			
Public fountains:					
Amusement parks, fairs, etc.	45–50	20 to 35 (per hour)			
Department stores, and hotel and office—building lobbies	45–50	4 to 5 (per hour per fountain)			

Location and Number of Drinking Fountains

Where a large number of people are to be provided with drinking water, as in offices and shops, the number of fountains will usually be determined by distance, character of occupation, and convenience of location. In small passenger stations, one fountain will usually be found sufficient. In larger passenger stations, fountains should be provided at convenient locations.

Where it is the practice to carry away water in containers (pails, bottles, etc.), as is often the case where heavy work is being performed (shops and enginehouses), provision should be made for adequate storage capacity of the cooler and for means of filling the containers.

Ice Cooling vs. Mechanical Cooling

Where ice is used the temperature of the water cannot be controlled, and ice has to be replenished frequently. Where mechanical cooling is used, the temperature of the water is controlled and only occasional maintenance is required.

Circulating System vs. Unit System

In the circulating system the temperature of the water rises in the pipe lines, and the waste water, which amounts to 55 to 60 percent of the water passing the bubblers, etc., cannot be employed as effectively in cooling, as is done in the units, and therefore the units in most cases are more economical to operate.

Cost of Operation, Maintenance, etc.—Mechanical Cooling

The current or fuel consumed is practically the only cost of operation of mechanical cooling equipment. The cost of maintenance for the first five years is usually small for first class equipment. Average costs may be obtained from manufacturers and users. For depreciation and obsolescence, an average life of ten years may be safely used.

Source of Supply

The source of the drinking water supply must have the approval of the proper health authorities. At outlying buildings, a well equipped with a hand pump may be employed where pure water is available. In a group of buildings, the water supply may be obtained from a driven well, using a pump of low capacity for distributing the water. An approved municipal supply, where available, is the most satisfactory source.

American Standards Association Requirements

Bubblers and fountains shall meet the requirements of the American Standards Association.

Conclusions

The selection of water-cooling equipment will usually be determined by local conditions. At locations where water service and sewer connections are readily available, the fixed mechanical cooling equipment will usually be the most economical. Where the expense of water and sewer connections is not warranted, the portable mechanical cooling unit or the portable iced cooler may be used.

The report is presented as information.

Appendix C

(6) Drop Pits, Jacks and Tables

A. G. Dorland (chairman, subcommittee), C. M. Angel, H. G. Dalton, J. P. Gallagher, E. G. Hewson, H. A. Pasman.

The following material relating to drop pits, jacks and tables, is recommended for inclusion in the Manual.

Pit jacks and pit tables are used in enginehouses, in shops, and in coach and freight yards. The pit jack is used to drop only one pair of wheels, provided the axle is free of pulleys, motors, or other attachments. The pit table is used to drop a pair of wheels or a complete truck.

Drop Pits

Drop pits are provided to accommodate pit jacks or pit tables and must be designed to take care of the particular equipment selected. Manufacturers of pit jacks or of pit tables can assist railway engineers in designing drop pits.

The requirements for jacks or tables are governed by the class of equipment to be handled, and the depth and size of the pits must be determined accordingly. The pits should be deep enough to handle the largest wheel along the pit, clear of all rail cover supports, and should be wide enough to allow side clearances for men to pass around the dropped wheels.

The pits should be well protected when in operation by safety gates or chains, and when not in use must be adequately covered. An overhead crane, a jib crane, a monorail and hoists, or a portable crane is usually necessary to handle this pit covering. When crane facilities are not available, pit covering platforms may be so designed that they may be lowered and brought beneath a working table top in a nested position to provide a pit opening at the releasing track.

The area around the drop pit should be designed to resist wear due to blocking and the heavy wheel loads. These surfaces may be of reinforced concrete, wood blocks or asphalt blocks on a concrete base, preferably reinforced concrete.

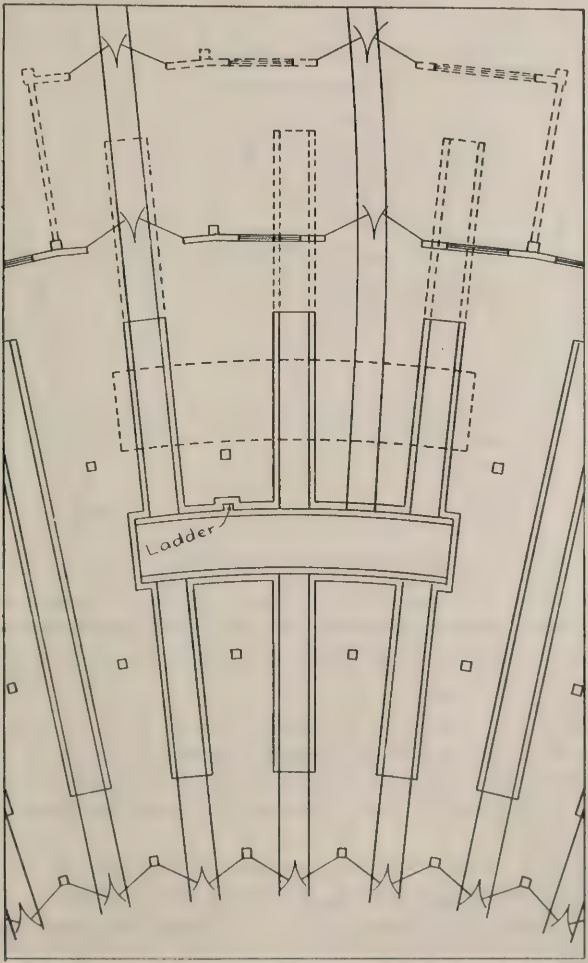


FIG. 1—Showing One Three-Track Drop Pit for All Locomotives and Tender Wheels. Dashed Lines Indicate Suggested Location When Stalls Are Extended.

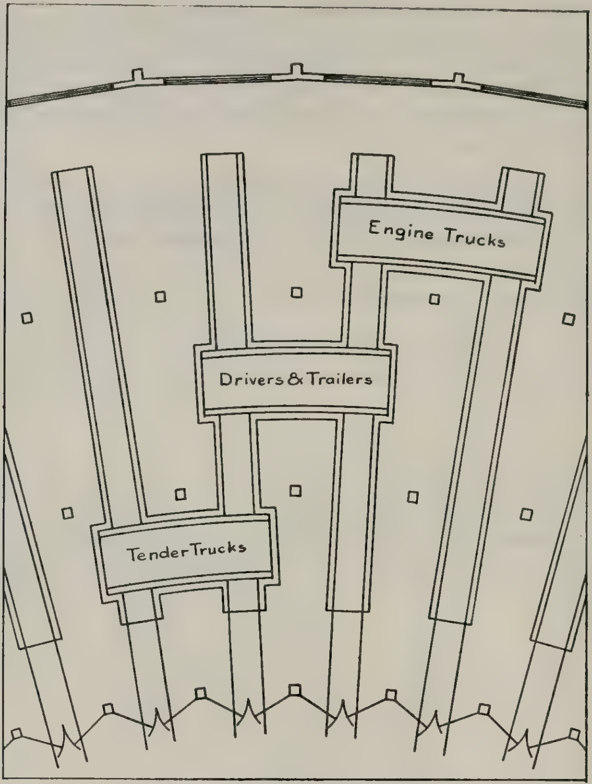


FIG. 2—Showing Three Two-Track Drop Pits.

The pit should be well lighted. This may be done by floodlights or other overhead lights, or by recessed side lights in the side and end walls, together with outlets for extension cord lights. Ladders, recessed into the wall, should be provided in each drop pit.

If the bottom of the pit is too low to have suitable drainage by gravity, a sump must be provided, with a pump.

In enginehouses it is advisable to install a service track or tracks between the regular enginehouse tracks, these tracks to extend out through the end of the enginehouse into the back shop. One such track is shown in Fig. 1. This will allow the full use of the pit jack or pit table on all tracks served and still allow for the removal of wheels directly to the back shop.

It is desirable to construct the stalls being served by the drop pit of sufficient length to handle all work with closed doors in cold and inclement weather.

The support of the rails across the pit for pit jacks should be designed so as to be readily removed.

Fig. 1 shows one three-track pit in an enginehouse, so located and constructed as to take care of all wheel work. Dashed lines indicate the location of the pit when these stalls can be extended.

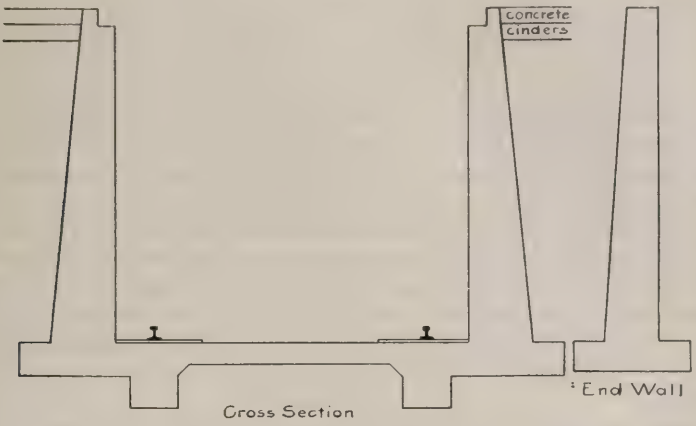


FIG. 3—Showing Typical Drop Pit for Drop Pit Table.

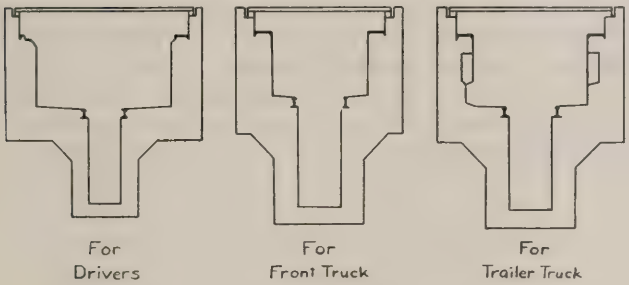


FIG. 4—Typical Sections for Drop Pits for Jacks.

Fig. 2 shows three two-track pits in an enginehouse, the one nearest the turntable for handling tender trucks, the center one for drivers and trailers, and the third one for front trucks.

Fig. 3 shows a typical section of a drop pit and a view of the end wall. This is for a pit table.

Fig. 4 shows three sections of drop pits for pit jacks; one for drivers, one for front trucks, and one for trailer trucks.

Pit Jacks

The pit jack is used in places where only one pair of wheels is to be removed. The majority of these jacks are equipped at the upper end with a half-circle groove which is placed under the center of the axle of the pair of wheels to be lowered. Many installations include a table top at the end of the jack.

The jack may be operated either by hydraulic or electric power. The jack is mounted on a truck which can be moved to another track in order to release the wheels.

Pit Tables

Pit tables have a platform table top, or in some cases, a plurality of detachable table tops which may be lowered and moved to the special wheel-removing track or to another track for removal of the wheels, by first nesting the table top at the releasing track below and against the table top supporting the wheels to be removed.

Pit tables may be raised and lowered by hydraulic or electric power. Some pit tables are four-screw electrically operated, and may be built so as to be self-locking in any position. It is safer to have the control switches outside of the pit. Some of the latest designs enable the table top to be raised or lowered at the rate of four feet per minute. Many of the modern tables use spring-operated take-up reels for the power cable.

The four elevating screws are near the corners of the table, which may be held at any height with an unbalanced load. Provision is made for elevating the top five inches above the floor so that certain wheels may be raised a corresponding distance in order to perform work necessary on tires or spring rigging. These tables vary in length up to 22 feet.

In order that complete six-wheel tender trucks or two or four-wheel trailer trucks with boosters can be dropped complete on an 11-foot table top, single or double shoulder pits may be placed beside the main drop pit. These shoulder pits are about 24 inches deep from the base of rail, and of a width to suit the needs. They are equipped with swing gates pivoted to the side walls, are self supported on their outer ends, and have rails on their tops. When swung along the track they are locked to the table top and serve as bridges over which the equipment is moved.

Pit tables for Diesel-electric locomotives should be large enough to handle complete trucks or single pairs of wheels with motors. At some terminals these locomotives are being handled by four portable jacks.

Report of Committee 13—Water Service, Fire Protection and Sanitation

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Committee.

To the American Railway Engineering Association:

Your committee respectfully reports on the following subjects:

1. Revision of Manual (Appendix A). Progress report.

2. Cause of and remedy for pitting and corrosion of locomotive boiler tubes and sheets, with special reference to status of embrittlement investigations (Appendix B). Progress report.

3. Value of water treatment. Progress in study. No report.

4. Progress being made by federal or state authorities on regulations pertaining to railway sanitation, collaborating with Joint Committee on Railway Sanitation, AAR. Progress in study. No report.

5. Conditioning water for vapor heating boilers on Diesel powered trains (Appendix C). Final report, submitted as information.

6. Report on new types of pipe and their application to railroad water service (Appendix D). Final report, submitted as information.

7. Methods for rejuvenating deep wells (Appendix E). Final report, submitted as information.

8. Fire extinguishers—their types and uses (Appendix F). Final report, submitted as information.

9. Use and application of chemicals for preventing deposit in pipe lines (Appendix G). Final report, submitted as information.

The Committee on Water Service, Fire Protection and Sanitation,

B. W. DeGeer, *Chairman.*

Bulletin 414, December, 1939.

Appendix A

(1) Revision of Manual

E. M. Grime (chairman, subcommittee), C. B. Bryant, G. E. Durham, J. J. Laudig, G. F. Metzdorf, R. H. Miller, J. A. Russell, H. W. Van Hovenberg.

The following revisions in specifications are recommended:

Tank Hoops

The specification covering material to be used for tank hoops was adopted in the year 1920. This appears on pages 13-23 of the Manual and covers wrought iron. This material costs considerably more than steel and it is felt that there is no good reason why tank hoops conforming to the specifications adopted for bridge steel should not be satisfactory. It is therefore recommended that the following be substituted for what now appears under the heading of Material:

Tank hoops shall be made of steel conforming to all of the requirements for quality, strength, inspection and test given in ASTM specifications for bridge steel A7–36.

Analysis of Hydrated Lime

On page 13–57, under section (b) *Procedure,* the third sentence reads: "Dilute to the mark and shake thoroughly for approximately 5 minutes."

To conform with actual procedure revise this to read: "Make up to the mark with 10 percent sugar solution and shake thoroughly for approximately 5 minutes."

Appendix B

(2) Cause of and Remedy for Pitting and Corrosion of Locomotive Boiler Tubes and Sheets

With Special Reference to Status of Embrittlement

R. E. Coughlan (chairman, subcommittee), R. C. Bardwell, W. M. Barr, W. L. Curtiss, J. H. Davidson, G. E. Durham, E. M. Grime, H. M. Laudemann, O. E. Mace, Ray McBrian, E. R. Morris, R. M. Stimmel, J. B. Wesley.

"Embrittlement", or, as it is now called, "intercrystalline corrosion", in rivet seams of locomotive boilers has been encountered and definitely identified on a number of American railroads. It is probable that in some slight degree, and perhaps without identification as intercrystalline corrosion, the trouble has been encountered on many railroads. It is, of course, difficult to arrive at figures for replacement costs on locomotives having such trouble, although recently it has been estimated that this type of corrosion results in a loss of some $500,000 per year on American railroads.

Intensive investigation of the problem has been generously supported by the Association of American Railroads, as well as by several of the leading engineering organizations, private industries and the Bureau of Mines. To date, this study has produced a coherent explanation of the processes and factors that allow such cracking to occur in a riveted seam; devices which, when attached to a locomotive, will determine whether or not the water will cause cracking; and chemical methods for feedwater treatment to make the water safe for locomotive use.

During the past year, your committee has been in continued close contact with the work done at the Bureau of Mines and the following report is offered as current information.

How Embrittlement Occurs

For many years the mechanism that allowed a solution to produce embrittlement or intercrystalline cracking was a profound mystery. Details are still not clear but an explanation can be offered that will fit the experimental facts now available.

Chemical Action and Stress Must be Present

It is well known that in many service conditions steel will corrode or rust; also under more limited conditions this rusting will occur only at certain restricted points to produce deep holes or pits. Steel is made up of crystals held together by thin bands of material designated as grain boundaries. These boundaries are known to have different chemical properties from the crystals, therefore certain corroding solutions may exist that instead of causing random distribution of holes or pits over the metal surface, will confine all the attack to the grain boundaries, separating the crystals from each other and eventually allowing the metal to fail. As a very crude illustration the action might be likened to removal of the mortar from between the bricks in a wall to allow the structure to collapse.

It is unfortunate that the solutions that have been found most desirable in a boiler from the standpoint of preventing rusting and pitting of the tubes and drum are the very ones most prone to cause embrittlement in the riveted seams. In many cases it is therefore desirable to establish the necessary conditions to prevent pitting and then add chemicals to prevent embrittlement.

Unlike rusting and pitting, however, embrittlement seems to occur only when the metal is under stress, and mainly stress in tension. These stresses arise from the structural load, from the steam pressure, or from cold working of the metal. Laboratory study indicates that this latter factor is of the utmost importance. The cold bending of a sheet to form a locomotive drum will at times introduce enough stress to make embrittlement attack possible. Cold distortion of the metal during riveting of a seam may be even more severe.

To prevent embrittlement the pressure and structural stresses in the seam should not be excessive and all possible care should be exercised to see that they are not localized for a crack may be started from one point that will be difficult to stop. Above all else, however, the cold working of drum, butt strap, and rivet metal should be kept at a minimum.

It is believed that careful design and fabrication of locomotive boilers can prevent a large portion of the cracking in spite of bad water conditions.

Concentration of the Boiler Water in the Riveted Seam

Contact of a normal locomotive boiler water with the riveted seam will not cause intercrystalline cracking. If there is a slight leak through the seam, deposits of solids are frequently seen at the outer edge and when the seam is torn apart, are found between the drum sheet and butt straps as well as around the rivets. To create such deposits which are made up of the so-called "soluble salts" the boiler water must concentrate several hundred fold. This concentrated solution in contact with the stressed metal is the one that causes embrittlement.

To produce concentration in this manner the leak must be very slow. One that can just be detected through the formation of a very faint haze of steam on a cold mirror held over the point of leakage is very dangerous. Such leaks are so small that they may not be detected during a cold pressure test on the locomotive.

A boiler that shows deposits of white solids at the seam edges may be in serious danger of embrittlement. Fabrication should make the drum just as tight as possible, for it is believed at the present time that intercrystalline cracking cannot occur in a locomotive boiler in the *entire* absence of leakage.

Testing Devices

The embrittlement detector, a very simple device for direct attachment to a locomotive, has been developed to measure the embrittling action of the boiler water. The water circulates through a block, to which a specimen is clamped and a slow leak creates concentrated solution in contact with the stressed area of the specimen. If the water is embrittling the specimen will crack. When this occurs chemical treatment is added to the feedwater and the test repeated to prove that the water in non-embrittling. These devices are now in use on a number of railroads throughout the United States.

Summary

Intercrystalline or embrittlement cracking is not due either to water conditions or boiler construction alone, but to a combination of factors that simultaneously create the following conditions:

1. A boiler water which when concentrated will produce embrittlement or intercrystalline cracking.
2. High stress in the metal. This may result either from cold work or external applied stress.
3. Formation of a film of concentrated solution as a result of slow leakage.
4. Contact of the film of concentrated solution with the boiler metal in the region of high stress.

The first factor is in partial control of the chemist, the second probably depends on the design and workmanship used in the boiler construction, the third depends on design and construction as well as conditions of service, while the last one would seem to be pretty much in the hands of fate.

Protection From Embrittlement

It should be possible to prevent embrittlement by eliminating any one of the four factors that have been listed. On locomotives already built and in service the simplest and least expensive remedy seems to be water treatment. In the past successful pursuance of this course has been impossible because of incomplete and at times totally wrong information concerning embrittlement. Even at present, feedwater treating methods while apparently successful are still in the experimental stage. Fortunately it is now unnecessary to wait until a locomotive boiler cracks to designate a water treating method as ineffective, for a test run with the embrittlement detector will crack a specimen and give warning of dangerous conditions in a short time.

While water conditioning may prevent embrittlement, this offers not the slightest excuse for poor boiler design and bad workmanship that provide the other necessary conditions to start and promote cracking. In every case of embrittlement cracking the boiler manufacturer should be willing to assume and shoulder his full responsibility where poor design, bad shop practices or poor workmanship are evident.

Thus far, the investigation at the Bureau of Mines has been confined largely to a study of chemical methods for treating the feedwater to prevent embrittlement. Some engineers have thought that sodium sulfate was satisfactory for this purpose, but this idea is not substantiated by laboratory work, nor apparently by railroad experience. A few organic chemicals have been found, however, that seem to be satisfactory protective agents.

The Use of Sodium Sulfate

As a result of a statistical study of stationary boilers the conclusion was reached by a few engineers that maintenance of certain amounts of sodium sulfate in a boiler water would prevent embrittlement. A subcommittee of the Boiler Code committee of the American Society of Mechanical Engineers later adopted this idea as the basis for the embrittlement code, in spite of the fact that the railroads had submitted statements indicating that their experience was apparently in disagreement with this belief.

In the past a tendency has existed to interpret evidence from stationary boilers largely with the idea that if a water were embrittling the boiler would crack. Therefore, if an alkaline boiler water contained sodium sulfate and the boiler did not crack, this was taken as partial evidence that the sodium sulfate rendered the water non-embrittling. When applied to an individual case the present much clearer understanding of the embrittling problem makes the fallacy of such reasoning apparent. Even though the water is embrittling, the boiler will not crack unless simultaneously it develops that (1) leaks of just the right size allow concentration take place, (2) certain areas of the boiler metal are highly stressed, and (3) the stressed metal is in contact with the concentrated solution. Therefore if the boiler does not crack this does not necessarily mean that sodium sulfate is protective, but may just as well mean that the boiler was well built and cracking would not have occurred in the entire absence of sodium sulfate.

It is certain that several factors are involved in the cracking of a boiler drum aside from the condition of the water. Therefore it is going to be difficult if not impossible to isolate the effect of a given feedwater treatment in preventing cracks from a simple study of statistics on operating boilers. By the use of the embrittlement detector the cracking action of the water alone can be determined. Up to the present time even high concentrations of sodium sulfate have not stopped cracking of detector specimens in laboratory or plant tests.

Straub* has recently suggested that sodium sulfate and sodium chloride will prevent embrittlement. Plant and laboratory tests with the embrittlement detector have not confirmed this idea at all.

The Use of Organic Materials

Extensive study has not yet revealed any inorganic compounds, which are definitely without undesirable properties in a boiler, and which at the same time will prevent embrittlement. Therefore search for a material with these desirable properties has been made in the field of organic chemicals, with some degree of success.

In the pressure range normally used in locomotive operation, lignin-containing materials, as represented by sulfite liquor, will prevent cracking in detector specimens of boiler flange steel. Sulfite liquor is not expensive and its use on a considerable number of railroads has shown that it creates no operating difficulties. In several cases its effect on the embrittling action of the water is being closely followed with detectors attached to the locomotives. Practical tests of this type will furnish data of the utmost significance.

One American railroad, during the period 1912 to 1926 reported 221 engines cracked through embrittlement. In this latter year lignin compounds were introduced into the feedwater in conjunction with an anti-foam treatment. A decrease in cracking was noted and the treatment has been in continuous use since that time. From 1926 to 1938 only eight cases of engine cracking have been reported. At the present time the road is entirely free from this difficulty and in view of the fact that laboratory tests show the lignin to be a good protective agent, it may be reasonable to assign the major portion of the improvement to the use of this compound. Statistical evidence of this type may or may not be cited since it is obvious that over a period of years many changes might have been made aside from those in water conditioning. This whole case could be made a good deal clearer by the use of the embrittlement detector to determine the action of the waters before and after lignin treatment. It is hoped that the detector tests now under way on other railroads will demonstrate less equivocally the action of the lignin compounds.

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* F. G. Straub and T. A. Bradbury, Boiler Water Treatment New Methods for Preventing Embrittlement. Mechanical Engineering, pp. 371-376, May, 1936.

Quebracho, another organic compound, has been found suitable in the laboratory for preventing intercrystalline cracking over the pressure range from 200 to above 500 lb. It is effective not only in boiler flange steel but also in specimens that have been cold worked before insertion in the detector. In general it is probably too expensive for use in locomotives but it has been extensively applied in stationary boilers. Coupled with a powerful effect in preventing embrittlement it will also remove oxygen from the boiler water and apparently exert a marked dispersing action on solid particles precipitating in the boiler water.

In the past one of the foremost objections to the use of organic material has been the lack of a chemical test for determining their concentration. This has been overcome by the development of a fairly rapid colorimetric method that may be used to estimate lignin-containing materials such as waste sulfite liquor as well as quebracho, and several other similar compounds. This method has greatly helped in the intelligent application of organic treatment for preventing embrittlement.

Conclusions

This exposition comprises an attempt to develop, on the basis of information now available, a logical viewpoint for the entire process leading to embrittlement cracking. The fundamental chemistry of the attack depends on the preferential corrosion of the grain boundaries with respect to the crystals of the metal, but it should be noted that stress is apparently a necessary prerequisite for dangerous cracking. Embrittlement is not caused by contact of the metal with a dilute boiler water but instead by contact with a solution resulting from concentration of the water as it leaks and permeates through the riveted seam.

For embrittlement to occur in a locomotive boiler combined conditions must exist as follows: (1) an embrittling water, (2) high cold working or applied stress in the metal, (3) leakage or concentration in the riveted seam, and (4) contact of the concentrated solution with the stressed metal.

These factors clearly indicate that only a portion of the problem is in the hands of the feedwater treating chemist. The boiler manufacturer must bear his responsibility to see that design and cold working stress are kept at a minimum and that the seams are so constructed that they can be maintained essentially "leak free".

At the same time, since the embrittling or non-embrittling nature of the water is only one factor in the problem, it becomes difficult to interpret stastistical data from operating boilers to determine the effectiveness of a given chemical treatment in preventing cracks. This may indicate that incorrect interpretation has been applied to the cases which were believed to indicate that sodium sulfate would stop cracking. The old contention of several of the railroads that this salt was not satisfactory in locomotive boilers may then be correct, and furthermore is logical, since railroad observations are based on so many more units that the chances are much better for obtaining the combination of conditions necessary to cause the cracking that will show the ineffectiveness of a given treatment. For instance, two railroads in the United States that have suffered most severely from embrittlement have a combined total of more than 3,000 locomotive boilers on which to base their observations. Individual cases of cracking will run well over 500 with approximately 400 engines involved. The number of engines actually cracked is probably greater than the total number of boilers originally considered in stationary practice as the basis for the present code. From this extensive experience the men responsible for the feedwater treatment on these roads do not believe that sodium sulfate is a satisfactory protective agent.

That it is costly and undesirable to measure the ineffectiveness of a given treatment to prevent embrittlement by allowing a locomotive boiler to crack is perfectly apparent. Now, the evidence points strongly that this can be avoided by the direct attachment of an embrittlement detector to the locomotive. At the same time, this unit will make it possible to classify the embrittling action of boiler waters, without introducing variables of boiler construction. To date these tests have not shown that sodium sulfate will stop cracking.

No inorganic salt or combination of inorganic salts has yet been found entirely suitable for use in the boiler to prevent embrittlement. Organic materials such as sulfite liquor and quebracho are apparently much more successful. At the present time the sulfite liquor seems most suitable in locomotive operation. A method of analysis has been developed to determine the concentration of this material in the boiler water.

Present evidence indicates that sulfite liquor, found satisfactory for preventing embrittlement in the laboratory, may also have played a major part in the last 12 years in eliminating embrittlement on one railroad that had suffered from this trouble in a most aggravated state. A second railroad that has been using the material under controlled conditions for over a year is beginning to obtain evidence indicating a definite decrease in cracking.

With further laboratory testing as well as co-operative testing by the railroads, it is hoped to eliminate the embrittlement problem from railroad operation completely.

Appendix C

(9) Conditioning Water for Vapor Heating Boilers on Diesel Powered Trains

Ray McBrian (chairman, subcommittee), W. M. Barr, R. E. Coughlan, J. H. Davidson, J. P. Hanley, A. W. Johnson, H. M. Laudemann, E. R. Morris, S. E. Printz, R. M. Stimmel, J. E. Tiedt.

Vapor boilers as used for heating Diesel powered trains, require water conditioning to prevent scale formation, pitting and corrosion.

Type of Equipment

The coil steam generator is a forced-circulation water-tube unit, having a rated capacity of 2,250 lb. of water evaporation per hour. Only one to two minutes is required after starting the unit with cold water, to develop 200 lb. steam pressure.

These units are fully automatic, burn Diesel engine oil, and are equipped with safety provisions against any kind of failure. The ratio of evaporation is approximately 12 to 1.

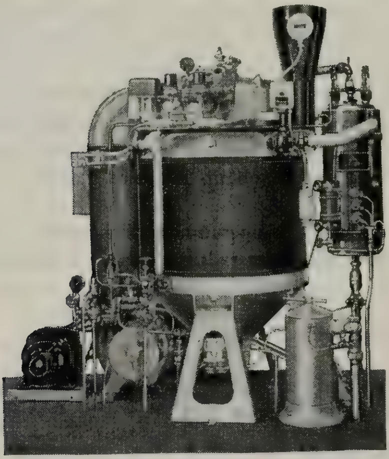
The construction of the steam generator is such that the combustion chamber is completely surrounded by the coil assembly. The ends of the coils are so shaped that an effective seal is made to prevent by-passing hot gases. The coil construction is so arranged that a complete stagger is provided, with free flow for gases, which are split up into narrow films. The coils are designed and arranged to allow for free expansion, but are held in firmly staggered relation for maximum heat transfer. Soot blowers are provided between the coil assemblies to remove the accumulated soot when required.

Constant ignition is used, so that should any of the safety devices shut off fire, it will automatically relight when normal conditons are restored.

The burner is of the steam-atomizing type. Air, however, is used for atomization when starting the steam generator. A changeover to steam atomization is made after the fire is started and the steam generator has been operating for ten minutes.

The fire travel is first horizontal, then downward and finally outward through the nest of coils. The travel of the water is opposite to that of the fire gases to insure maximum heat transfer.

During operation, an excess of water should be circulated through the coils. The excess water circulated is about 5 percent more than is required for evaporation into steam, but the generating unit is designed to operate properly with anywhere from 2 to 20 percent excess water circulation.



A Typical Train Heating Boiler.

The coils are wound with superimposed layers, giving a staggered passage to the hot gases. Each coil is continuous, being several hundred feet in length. This length is made up by butt-welding commercial lengths of steel tube (ASME S-17 specifications). The coils are assembled with sinuous spacers to locate the tubes, and block spacers to prevent settling. The block spacers are welded to both adjacent tubes at 180-deg. spacing. At 90 deg. to this, the block spacers are welded to one tube only. This is to allow for free expansion. The three separate coils are connected together so that the flow through the generator is in series and towards the fire. As these coils form one continuous tube, the importance of proper feedwater treatment is obvious.

Methods of Water Conditioning

There are three methods of water conditioning, as follows:

1. Proprietary compounds
2. Condensate
3. Exchange filters

1. Proprietary compounds have been used and are usually added to the water by a feeding device. Usually one pound of such material is added for each 1,000 to 1,500 gal. of water used. In addition to applying such internal treatment, it is necessary to blow down the steam separator once every three to five hours, and a complete blow down of both separator and boiler is made at the end of each trip.

In the use of proprietary compounds, it is necessary that the screen on the chemical pot be thoroughly cleaned with passive acid and water each time the unit is serviced at the terminal. This is due to the fact that with the use of proprietary compounds, carbonate of lime settles in the chemical pot and clogs the screen, unless the screen is properly conditioned.

It is also necessary, with this method of treatment, to clean the heater coils thoroughly at least every 30 days with passive acid or some similar proprietary treatment, washing coils thoroughly with water after such treatment before the boiler is again put into service.

2. Some roads with flash type boilers are collecting and using condensate from heating units or power plants, where such condensate is available. This has proved to be satisfactory where the condensate is conditioned by some anti-corrosion treatment.

3. Exchange filters are being used by some railroads for the removal of dissolved salts from solution, including the sodium salts.

These exchangers usually consist of three separate units, connected in series. The first two are filter beds, arranged in series, the first bed being known as the "cation exchanger", which removes the positive ions, or cations, such as those of calcium, magnesium, and sodium. The second bed removes the negative ions, or anions, such as the chlorides, sulfates, and nitrates, and is known as the "anion exchanger bed". The carbonate ions, or CO_2, which enter the system as bound CO_2 in the carbonates and bicarbonates of the raw water, are not removed in either of the anion or cation beds, but are released by aeration through a unit known as a "decarbonator".

Cation Exchange Filter

This filter usually uses phenolic hydroxyl, or sulphonic cation exchangers, which may be regenerated with acid. These organic materials are usually graded between 14 and 48 mesh per square inch.

In converting the dissolved salts in the raw water to the corresponding acids, an exchange reaction takes place. The positive ions, such as sodium, calcium, and magnesium, are all being replaced with hydrogen, which is supplied by the organic material. When the cation exchange material has removed its full capacity of sodium, calcium and magnesium, it must be regenerated. This is done by passing a dilute solution of acid through the bed. Any strong mineral acid will do, but sulfuric acid is generally used because of its lower cost.

The commercial rating of the cation exchange medium, as used by railroads, is dependent upon the analysis of the water to be treated and the operating conditions. Usually the exchangers have a rated capacity of about 7,000 grains per cubic foot as calcium carbonate. To determine the value of water which can be treated per cubic foot of cation exchange medium, divide the capacity (grains per cubic foot) by the dissolved solids.

The backwash rate for the cation exchange material depends upon the free board available. An upflow rate of 4 to 4.5 gal. per minute per square foot is sufficient to loosen the entire bed thoroughly and not result in an excessive bed loss. Usually one hour is allowed for each regeneration of the cation bed. The acid requirement for water treated with the cation medium usually equals D.S. (dissolved solids, grains per U. S. gallon) as calcium carbonate ($CaCo_3$) × (0.24) pounds of 66-deg. Baume sulphuric acid per 1,000 gal. of water treated. The acid can be diluted to a ten-percent solution in an acid vat and further diluted to a two-percent solution by an injector when being added to the bed. A two-percent acid strength appears to be about the optimum. Acid strengths much over two percent (Sp. Gr. 1.0118, or 1.7 deg. Baume) are not recommended.

Anion Exchangers

In this exchanger the negative ions, rather than the positive ions, enter into the process. The products usually used are resins derived by condensing aromatic amines with an aldehyde and an acid. It is a porous granular material and is graded between screens having 14 and 48 meshes per square inch.

In removing the acids from the cation effluent, the exchange reaction takes place with the participants in the reaction being the negative ions, such as the chlorides, sulphates, and nitrates. As an illustration, consider an acid influent containing hydrochloric acid. The chloride ion is taken up by the anion exchange medium and is replaced with an OH ion from the anion exchange medium, which unites with the hydrogen of the acid and forms water.

The effluent from the anion exchange filter will be free of dissolved salts and mineral acid and will contain carbon dioxide, which can be removed by a decarbonator.

When the anion exchange bed has taken its full capacity of negative ions, it must be regenerated with a solution of caustic soda or soda ash. Caustic soda gives better results because with soda ash regeneration the large quantities of carbon dioxide released during regeneration tend to cause bubbles, which channel the bed.

The commercial rating of the anion exchange material is dependent upon the ratio of chlorides to sulphates in the raw water, and upon the operating conditions. Usually they have an exchange capacity of 13,500 grains per cubic foot as calcium carbonate, and to determine the amount of water treated per cubic foot of the anion exchange material, divide the capacity by the sum of the total sulphates, chlorides, nitrates, and phosphates.

Slightly longer times for regeneration are allowed for this material; usually from one to one and one-half hours should be allowed. The rinsing of excess caustic soda following anion regeneration should be made with soft water. The flow rates, and backwash rates, are generally the same as for the cation exchange material. An upflow rate of 3 to 3.5 gal. per minute per square foot is usually sufficient to loosen the bed thoroughly.

The caustic soda requirements for regeneration of the anion unit equals ($Cl + SO_4$, i.e., chlorides plus sulphates grains per U. S. gallons, as calcium carbonate, $CaCo_3$) × (0.164) lb. of flake caustic soda per 1,000 gal. of water treated.

Decarbonator

The decarbonator usually consists of an open, corrosion-resistant container, such as vitrified clay sewer pipe, filled with Raschig rings made of a ceramic material. The water flows by gravity down-flow through the decarbonator, and because of the large amount of surface provided by the rings, is spread into thin layers. A counter current of air removes the carbon dioxide and carries it out the top.

Iron Removal

These exchangers will remove up to ten parts per million of dissolved iron and aluminum. When they are regenerated, they will remove more iron and aluminum.

Organic Matter

The exchangers will not impart organic matter to the water when used as instructed.

Limitations to the Exchange Process

The anion, cation exchange process can be used to treat any clear water at a temperature on not over 160 deg. F. and at any ph value below 10.

Figures on Cost of Operation

Below are typical operating costs, using the exchanger process, based on average raw-water hardness of 14.3 grains per gallon, average alkalinity of 8.0 grains per gallon, average operating acidity of 12.1 grains per gallon. The operating acidity shows the amount of negative or acid ions produced in water by passing through the first exchange unit and is in direct proportion to the amount of total chlorides and sulphates present in the raw water. Example:—For the months of April and May, 1939, costs as follows:

(Plant now in service, taken from operator's daily report)

Total Water treated	368,870 gal.
Average dissolved solids	23.1 grains (influent)
Average dissolved solids	1.4 grains (effluent) (per gallon)
Chemicals:	
H_2SO_4—4,558 lb. at 0.0195	\$88.88
NaOH— 882 lb. at 0.025	22.05
Wash Water:	
132,120 gal., at 10 cents per M gal.	13.12
Total cost	\$124.05
Cost per M gal. (exclusive of labor)	34 cents

Carbonaceous Zeolites

Where the raw water is low in chlorides and sulphates, the use of carbonaceous zeolites in combination with sodium zeolites offers another means to secure a feedwater of minimum scaling tendency and a reduced content of total dissolved solids. The usual sodium zeolites, which exchange their sodium base for calcium and magnesium (hardness), reduce this hardness to a minimum, but do not reduce total solids or alkalinity.

The hydrogen, or carbonaceous, zeolites are made of carbonaceous substances, which are prepared by any one of a variety of treatments of various carbonaceous materials, such as coal, lignite, or wood. The raw material, properly graded, is treated for extended periods with any one of a variety of chemicals such as fuming sulphuric acid, sulphur trioxide, chlorosulphuric acid, or zinc chloride, after which it is washed, stabilized as required, and finally screened to the desired size. The material can function in the usual sodium-zeolite cycle when it is regenerated with sodium chloride, but because of its unlimited resistance to acids, it can be regenerated with acid such as H_2SO_4 and HCl, in which case it operates in what is called a hydrogen-zeolite cycle, the H of the acid entering the zeolite and being later replaced by the cations Mg, Ca, or Na, as occurs in the cation exchangers. This type mineral is said to possess a very high operating exchange capacity on the order of 5,000 to 12,000 grains of cation (expressed as $CaCo_3$), removed between regenerations per cubic foot of zeolite.

The operation of the carbonaceous zeolite is the same as for the cation exchanger, and where used with the sodium zeolite, the effluents from sodium zeolite and carbonaceous zeolites are combined in correct proportions, so as to obtain a feed water which is free from hardness, low in dissolved solids, and of desired alkalinity.

This report is submitted for information.

Appendix D

(6) New Types of Pipe Coming Into Use and Their Application to Railroad Service

A. W. Johnson (chairman, subcommittee), R. L. Holmes, C. R. Knowles, H. F. King, O. E. Mace, G. F. Metzdorf, A. B. Pierce, W. G. Powrie, J. A. Russell, H. E. Silcox, R. E. Wachter, K. J. Weir.

For more than 100 years cast iron pipe has been the principal distribution pipe line material in the United States. Prior to 15 years ago most of this pipe was cast vertically in pits with sand molds. Within the past 15 years, more or less, the manufacture of cast iron pipe in horizontal molds by centrifugal process has been perfected. The centrifugal cast pipe has higher tensile strength, greater density of wall structure, and lighter weight, making it less expensive than the old sand-cast type.

The deterioration of cast iron pipe lines is usually in their carrying capacity, caused by tuberculation rather than in loss of strength of material. New type linings for cast iron pipe have been developed to replace the old tar coating, making the pipe more resistant to tuberculation. These linings consist of cement coatings up to ⅛ in. in thickness and spun bituminous materials like those used with steel pipe.

Cast iron pipe is characterized by high resistance to corrosion, long life, tuberculation with many waters unless well protected by coating, and a sharp sudden fracture in failure. Its tensile strength is 25,000 lb. per sq. in.

During the past several years, new cast iron water main construction has averaged in excess of 5,000 miles per year in the United States.

Coated and Lined Thin Wall Steel Pipe

Steel pipe has a high tensile strength (50,000 lb. per sq. in) making possible its use with comparatively thin wall sections. Within the last ten years it has been used to some extent in water works installations, with wall thickness about one-half that of standard weight steel pipe. Because of the corrodability of steel, its adaptability to this service is largely dependent on a satisfactory liner and coating. The bituminous enamel spun lining and outside coating give promise of having supplied the solution for the protection of steel pipe.

Standard coated 12-in. steel pipe with a thickness of 0.33 in. (given a 75-year estimated life) has an annual cost less than that of the spun-lined thin steel with a thickness of 0.1875 in. (given a 35-year life). It is just about as cheap on an annual cost basis to install heavier steel as to use the thin section with spun coating. The added thickness becomes its own corrosion protection and also furnishes a greater factor of safety during its entire life than is available with the thin section.

For pipe sizes of 12 in. and smaller the thin-wall steel pipe with spun bituminous coating has practically no advantage in first cost, but it does in sizes larger than 12-in. diameter.

Cement-Asbestos Pipe

Cement-asbestos pipe made of cement and asbestos fiber is characterized in appearance by a smooth semi-polished cement color. It has a tensile strength of about 4,000 lb. per sq. in with an elastic limit 90 percent of this ultimate strength. In fracture, cement-asbestos pipe more closely resembles cast iron than steel.

This type of pipe was first introduced in Italy and considerable quantities have been used throughout Europe. It was first introduced into the United States about 1926. The joints in cement-asbestos pipe are made with Simplex couplings which consist of a cement-asbestos sleeve and two rubber rings. The joint has considerable flexibility.

Due to the low tensile strength of cement-asbestos pipe material, the wall thickness of this pipe would probably have to be increased under conditions where high internal or external pressures, such as water hammer or loading, develop. However, all pipe lines should be designed for the respective classes of service for which they are intended, and properly protected by suitable relief valves or casings, if necessary.

In first cost and cost of making joints there is some advantage in cement-asbestos pipe over cast iron pipe. In the absence of exact records to prove how long this pipe will last it is reasonable to estimate its life at about 65 years. On the basis of this assumption, the annual cost compared to cast iron pipe at 100 years' life would be approximately the same.

Threaded service taps in cement-asbestos pipe are more apt to strip than those in cast iron or steel pipe, and it probably is best to figure on making taps by means of saddles.

Manufacturers' reports indicate that something like 600 miles of this pipe have been installed per year for the past two or three years.

Copper-Tubing

For inside water piping and outside service lines the recent development of copper tubing in small diameters has come into prominence. In first cost it is slightly higher than galvanized pipe, but because of its flexibility and the simplicity of making sweat lead joints its use has increased to a considerable extent.

This report is offered as information.

Appendix E

(7) Methods for Rejuvenating Deep Wells

J. P. Hanley (chairman, subcommittee), R. E. Coughlan, E. M. Grime, J. S. Hancock, A. W. Johnson, H. F. King, H. L. McMullin, A. B. Pierce, J. E. Tiedt, K. J. Weir.

The methods used for rejuvenating wells will vary according to circumstances or the particular condition of the well to be improved, and the application of the method may vary in different kinds of water-bearing formations and with local conditions. The well to be reconditioned should be studied as to age, type of pumping equipment, type and material of the well screen, the chemical analysis of the water and other pertinent conditions.

The redeveloping of wells generally requires agitation in various forms. Some wells may be improved by starting and stopping the pump at short intervals for a period of time, and even when other methods are used pump agitation is useful in cleaning the screen and breaking up incrustation. A simple and effective method of cleaning and agitation is provided by a plunger made of wood or other suitable material and of slightly smaller diameter than the well screen. The raising and lowering of this plunger rapidly in the screen from top to bottom breaks up and washes out the incrustation unless it is unusually tenacious or firmly lodged in the screen openings. In the latter case the screen may be filled with hydrochloric acid, dry ice or hypochlorite solutions which will usually remove the various types of incrustation encountered. At this point the chemical analysis of the water, composition of the incrustation, and the metal used in the screen should be studied in order to select the most efficient chemical and one that will not damage the well screen or equipment.

Low-pressure steam delivered into the screen by a pipe line has been used by some railways, but care should be taken to guard against eruptions of boiling water that may rise to the top of the well when this method is used without suitable protection.

The use of an air lift where sufficient water depth for adequate submergence is available is beneficial in cleaning debris from the bottom of wells. Air agitation also creates a surging action that tends to loosen incrustation and raise the pieces to the surface.

In cases where the particles are too large or heavy to be removed by a jet or wash line, a bailing bucket with a check valve in the bottom may be used and the heavy material removed by hoisting.

When none of these methods proves satisfactory the screen should be removed, cleaned and reset. This operation requires skilled wellmen and is generally more expensive than reconditioning without screen removal.

Descriptions of Some Reconditioning Projects

The Illinois Central reconditions from six to nine wells per year to improve production. Two wells at Gwin, Miss., 400 ft. deep, in sand formation, Artesian flow, one well installed 1912, and the other in 1915, were improved by light swabbing and application of the air lift. Deep flowing wells are easily damaged and require careful handling. Heavy agitation is not desirable. The production of these wells was increased 15 to 25 percent.

Four flowing wells at Gilman, Ill., 100 ft. deep 30 years old require rejuvenation at intervals of 4 to 5 years. A similar condition is encountered at Palestine, Ill., where three wells are reconditioned. The latter wells, however, do not flow. Iron oxide paste and slime collects inside and outside of the screens and the sand and gravel packs to such an extent that water production is seriously reduced. At both locations the well screens have been extracted, cleaned and reset with an increase in production of 30 to 40 percent.

The well at Pesotum, Ill., is 258 ft. deep and was installed in 1919. In 1928, 800 gal. of hydrochloric acid was introduced into the screen, which is 13 in. in diameter by 65 ft. long, by means of a 1½-in. iron pipe. This cleaned the screen and sand formation and the production was increased from 42 to 125 g.p.m. The acid cost was $160, and $40 covered the cost of labor. In 1933 and 1937 the well was rejuvenated by swabbing the inside of the screen with a wooden plunger and by pumping and bailing. The production was increased from 50 to 110 g.p.m. and the labor cost was approximately $90 for each cleaning. At Millington, Tenn., six 10-in. well screens were extracted, cleaned and reset in 1939. The combined production was increased from 5,000 to 17,000 gal. per hour and the labor cost was $720.

In 1931 the Atchison, Topeka & Santa Fe constructed a 24-in. diameter well 40 ft. deep at Enid, Okla. The casing and screen were made of concrete. A four-inch iron pipe was installed on the outside of the well casing with slots opposite the slots in the well screen and a surface connection provided for wash water. In 1938, after the production of the well had decreased from 54 to 10 g.p.m., the fine sand blocking the screen was removed by introducing water outside of screen that was pumped in from a tank car. After this exterior washing the production was increased to 40 g.p.m.

A well drilling company reports a case at Oxford, Miss., where a gravel-walled well with an iron screen was installed in 1912. In 1932 the screen became clogged and the capacity of the well decreased from 500 to 150 g.p.m. The static water level in the well was 80 ft., while the pumping level receded to 115 ft. The turbine pump was removed from the well and 500 lb. of dry ice was applied. The water became agitated so that it rose to the surface of the ground. The pump was replaced and a production test of 400 g.p.m. was secured.

The Northern Pacific rejuvenated the well at the terminal at Jamestown, N. D., which has a water consumption of 600,000 gal. per day. The water is obtained from a 12-in. well in gravel formation, 100 ft. deep. The screen is 15 ft. long. The static level was 11 ft. below the surface and the pumping level at 613 g.p.m. was 21 ft. when the well was drilled. In July, 1938, the production was found to have decreased to 346 g.p.m. and the pumping level of the water receded to 34 ft. The well was rejuvenated by introducing 100 gal. of hydrochloric acid into the bottom of the well screen through a 1¼-in. iron pipe, while a similar volume of water was pumped from the top of the well by a small hand pump. The acid caused violent agitation in the well and after standing 20 hours air agitation was also given the screen. After the pump was replaced, the production tested 505 g.p.m. The cost of the acid was $22.68 and the labor cost was $50. The estimated cost for renewing the well screen was $500.

At Sterling, Ohio, the Erie rejuvenated a 10-in. well 100 ft. deep by removing the screen and breaking up the packed formation with a drilling tool and then bailing out the fragments. The screen was reset, the formation washed and production was increased from 250 to 500 g.p.m. with a draw-down of 9 ft. as compared with 30 ft.

The Erie also reported on a gravel walled well at Crown Point, Ind., that was rejuvenated with dry ice. The production of this well had decreased to the extent that the pump would exhaust the supply in the well in 15 sec. of pumping, after which the pump would idle for 35 sec., the production being 110 g.p.m. during the pumping intervals. In February, 1939, 96 gal. of 18-percent muriatic acid was applied to the well, but this did not give satisfactory results. In April, 1939, 300 lb. of dry ice was dropped into the well in pieces of considerable size. Violent agitation for a two-hour period followed this treatment, after which the pump was replaced in the well and a test of 255 g.p.m. was secured without a break in the supply of water to the pump.

The Missouri Pacific uses electric detonators or dynamite caps to restore production from wells. Wells in sand formation ranging in depth from 50 to 125 ft. have been treated with satisfactory results. The usual method is to use a duplex 14 to 18-gage wire about 10 to 15 ft. longer than the depth of the well, fasten five caps about one foot apart on the wire at the bottom end, lower the caps to the bottom of the well and explode them with either two dry cell batteries or a standard blasting machine. The wire is then removed from the well, the exploded caps and their wires are detached and five more caps are attached in the same manner. Again the caps are lowered into the well, this time stopping at about the point where the top cap was previously exploded, repeating in this manner until the entire length of strainer has been exposed to these exploding caps. It may be necessary in some cases to repeat this procedure, depending on the formation and condition of the well. The pump is re-set and operated to remove mud and incrustation from the well. The material used can usually be obtained from the company stores at nominal cost. Recently the delivery from two 8-in. diameter well, from 150 to 175 ft. in depth, located at Wynne, Ark., was increased from less than 75 g.p.m. to more than 150 g.p.m. At other locations similar improvement has been observed.

In cases where the strainer is in poor condition, it is advisable to put a heavy wire screen or netting around the caps before lowering into the well so as to hold them in the center of the screen, thereby lessening the danger of damage.

The foregoing comments deal with wells in gravel and unconsolidated formations. Wells in rock should also be considered as such wells are numerous and important in sections of the country where water is obtained from limestone, St. Peters, Potsdam and other rock formations. The St. Peters and Potsdam formations are the deepest and usually contain the most abundant supply of water. Some formations of lime rock produce limited amounts at much lesser depths from fissures and seepage through favorable sections. If a well in rock is properly cased through the caving formations and the initial supply is sufficient, the well will usually require less reconditioning than wells in unconsolidated formations. When installing a rock well the railroad should deal with a reputable driller, experienced in rock drilling and familiar with the formations in the locality. The approximate depth, geology and probable analysis of the water should be considered in advance. The top section of the well should be started with a diameter sufficient to permit a progressive decrease in the casing diameter where it is necessary to use casing through caving formations, and to finish the bottom section sufficiently large for the production desired. The casing should be of a character that will resist water and soil corrosion and to have the necessary structural qualities for the expected life of the well. Where structural elements are not sound, or the casing corrodes or fails, caving material enters, obstructs the water inlet and makes it necessary to recondition the well. This may sometimes be done by inserting a smaller casing inside the old one and by breaking up the debris in the well with a drilling tool, and bailing and pumping out the fragments. In cases where the fissures and water passages become obstructed in the formation the use of suitable chemicals and mechanical and air agitation are useful in dislodging the obstructions. In very difficult cases of inadequate production in rock wells explosives are sometimes used. In wells approximately 400 to 700 ft. deep dynamite is generally used for breaking up the obstructions. This method is not desirable for shallow wells as the ceiling and nearby surface conditions may be disturbed, and caving material admitted. In wells of approximately 700 to 1,800 ft. deep, heavy charges of nitro-glycerin have been exploded after milder remedies failed to increase production. Following the explosions the fragments are removed from the well, the formation is agitated with air or water and the well tested for improvement.

Conclusions

1. In attempting to increase the production of wells, agitation by mechanical means, by air, pumping, bailing and back washing should be first tried.

2. If satisfactory results are not obtained by agitation, suitable chemicals should be introduced into the well screen. The chemicals should be adapted to the particular type of incrustation to be corrected and the pumping equipment should be removed while the chemicals are in the well.

3. The extraction, cleaning and resetting of well screens insures a very thorough job if a crew of experienced well men is available.

4. The use of explosives in breaking up obstructions in rock wells of medium to greater depth is sometimes beneficial. This method is not advisable in shallow rock wells or in wells in unconsolidated formations. However, the explosion of dynamite caps or detonators only in the latter wells has improved production.

5. In order to reduce the liability for reconditioning work, the use of sound construction, suitable screens and casing and experienced drillers familiar with the local formations is recommended at time the well is installed.

This report is offered as information.

Appendix F

(8) Fire Extinguishers—Their Types and Uses

G. F. Metzdorf (chairman, subcommittee), C. B. Bryant, F. A. Feikert, J. P. Hanley, J. J. Laudig, W. A. McGee, H. L. McMullin, W. A. Radspinner, H. E. Silcox.

The beginning of a fire is usually small. When a fire is small it can be snuffed out easily by quenching and cooling it with a pail of water or by blanketing and smothering it with a rug. Such action at the start of a fire may be more effective than the work of an entire fire department a few minutes later. The familiar water pail is probably the oldest type of fire extinguisher. Water pails are handy for so many uses and so often used for other things even when set aside for fire use that extinguishers were invented which, not being useful for anything else, are more likely to be available when wanted for the emergency of a fire.

Fires are not all alike. If fires were all alike any extinguisher might do. In many cases a pail of water would do, but on some fires a pail of water might be worse than useless and another type of extinguisher might be of vastly superior effectiveness.

For all practical purposes there are three general classes of fires:

Class A—Fire in ordinary combustibles like wood, paper, textiles, rubbish, etc.
Class B—Fires in flammable liquids, greases, etc.
Class C—Fires in electrical equipment.

This classification of fires is used for the purpose of assigning the types of extinguishers best suited for extinguishing each particular class of fire. Fires can be suppressed by cooling the burning substance below the temperature of combustion, or excluding the oxygen of the atmosphere from contact with the substance, or some combination of the two.

There are various types of first-aid fire appliances. Each type is of value, but all are not equally effective upon various classes of fires. Extinguishers must be chosen to extinguish the class of fire that may be anticipated. The following tabulation shows the common types of extinguishers which are adaptable for the three general classes of fires:

For Ordinary Class A Fires

The following appliances are adaptable to put out fires by the cooling effect of quantities of water or water solutions:

Soda-acid extinguisher
Foam extinguisher
Calcium chloride (non-freezing) extinguisher
Loaded-stream extinguisher
Pump-tank extinguisher
Water pails
Hand hose

For Fires in Flammable Liquids, Greases, Etc.—Class B Fires

The following appliances are adaptable to put out fires by smothering them with a foam or a heavy incombustible gas, etc.:

Foam extinguisher
Loaded-stream extinguisher
Vaporizing liquid (Carbon tetrachloride base) extinguisher
Carbon dioxide extinguisher
Dry chemical extinguisher
Sand pails (special use only)

Sand pails are intended for special uses and should usually be supplemented by other kinds of extinguishers.

For Electrical Class C Fires

The following appliances deliver a non-conducting extinguishing agent which can be safely used on electrical apparatus:

Vaporizing liquid (carbon tetrachloride base) extinguisher
Carbon dioxide extinguisher
Dry chemical extinguisher

Other types of extinguishers, when used on fires in electrical equipment, may cause a short circuit through the extinguishing stream, thus exposing the operators to the danger of a personal injury.

FIRE EXTINGUISHER CHART

Types		*Foam*	*Soda-Acid*	*Anti-Freeze*	*Vapor. Lq.*	*Car. Dioxide*
Chemical (Obtain Charges from Manufacturer)		Sol. of Aluminum Sulphate and Bicarbonate of Soda with foam agent	Bicarbonate. of Soda Solution and Sulphuric Acid	Special Charges	Carbon Tetrachloride with Important Components	Carbon Dioxide
Operating Method		Invert	Invert	Invert or Inv. & Pump	Pump or Open Valve	Open Valve
Extinguishing Effect		Blanketing	Cooling and Quenching	Coolng and Quenching	Blanketing	Blanketing
Protection from Freezing Required		Yes	Yes	No	No	No
Use on Class "A" Fires	Wood, Rubbish, Textiles, etc.	Yes	Yes	Yes	No—but has some value on small fires	No—but has some value on small fires
Class "B" Fires	Oils, Greases, Paints	Yes	No	No	Yes Blanketing	Yes
Class "C" Fires	Live Electrical Equipment	No	No	No	Yes	Yes

Unit of First-Aid Fire Protection

Extinguishers are classified in units of first-aid fire protection, depending upon their relative extinguishing capacity under average conditions of use. For convenience in measuring the fire protection afforded by extinguishers it may be said that a standard fire which could be extinguished by a unit, such as one 2½-gal. soda acid extinguisher, or equivalent (one 2½-gal. foam extinguisher or one 5-gal. pump-tank extinguisher, etc.), it would take two 1¼-gal. soda acid extinguishers or equivalent (two 1-qt. carbon tetrachloride extinguishers or five 12-qt. water pails, etc.) to make a unit to extinguish the same standard fire.

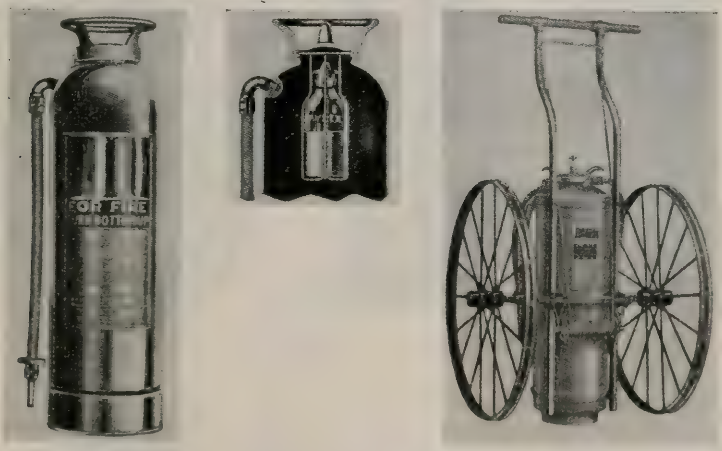
Distribution of Units

Where there is a relatively small amount of combustible material present, as in office buildings, public buildings, etc., extinguishers should be distributed on the basis of one unit for each 5,000 sq. ft. of floor area or not over 100 ft. travel from any point to the nearest unit on the same floor level.

For ordinary combustible occupancies, such as storehouses, warehouses, machine shops, etc., there should be one unit for each 2,500 sq. ft. of floor area or not over 50 ft. of travel from any point to reach the nearest unit on the same floor level.

Where an extra hazard may be found, as in a wood working shop, an oil house, a paint-spraying operation or other hazardous occupancies, the distribution should include one unit for each 2,500 sq. ft. of floor area or not over 50 ft. of travel from any point to reach the nearest unit on the same floor level, plus such additional units for special hazards as are found to be desirable by careful study of the particular hazards.

Hand fire extinguishers shall be conspicuously located where they will always be readily accessible and so distributed as to be immediately available in the event of a fire. When hung on hangers, brackets, or placed on shelves they should be so arranged that their upper rims will be not more than five feet above the level of the floor.



Soda-Acid Extinguishers

Soda-Acid Extinguishers

Approved hand fire extinguishers are made in two principal sizes: one having a liquid capacity of 2½ gal., the other, 1¼ or 1½ gal. The chemicals used are bicarbonate of soda and sulphuric acid. A small bottle, held in place in the upper portion inside of the tank, contains the sulphuric acid. The body of the tank contains the bicarbonate of soda in solution with water.

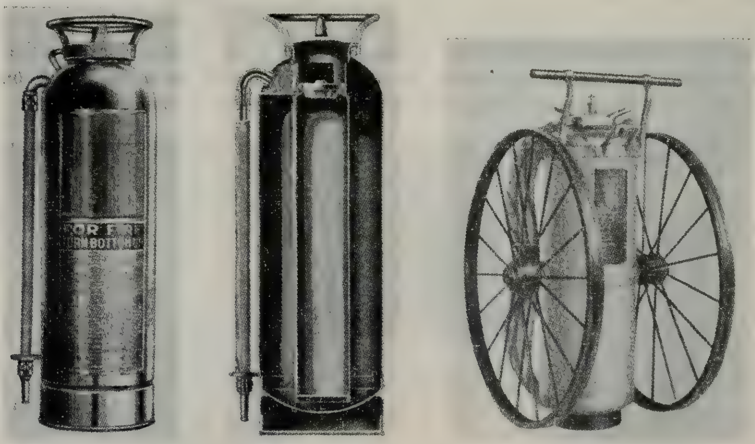
Method of Operation—The extinguisher is carried by means of a top handle and inverted to be used. This operation empties the small bottle of acid into the solution of bicarbonate of soda and water. The resulting chemical action generates carbon dioxide gas and the pressure to expel a forceful stream of liquid through the hose. While the stream is usually most effective if used close to the fire, in case of necessity it can be directed effectively from a distance of 30 to 40 ft. horizontally.

Suitability—These appliances are best suited for ordinary Class A fires. They are of some use on certain Class B fires, such as in floors soaked with oils, greases, etc., but are not effective on fires in flammable liquids or greases in open containers. This type of extinguisher is subject to freezing and must be protected where continued temperatures lower than 40 deg. F. will be encountered.

Unit of Installation—One 2½-gal. or two 1¼ or two 1½-gal. extinguishers of this type are considered a unit of first aid fire protection.

Foam Extinguishers

This type of hand fire extinguisher is made in three principal sizes: One having a liquid capacity of 1¼ or 1½ gal. the others, 2½ and 5 gal. The chemicals used are bicarbonate of soda and a foam stabilizing agent dissolved in water for the outer compartment and aluminum sulphate dissolved in water for the inner cylinder.



Foam Extinguishers

Method of Operation—The extinguisher is carried by means of a top handle and inverted to be used. When the two solutions mix foam is produced and pressure is created within the container which expels the foam through the hose. While the stream is usually most effective when directed from a distance, it may be used close to the fire. In case of necessity it can be directed effectively from a distance of 30 to 40 ft. horizontally.

For best results in flammable liquid fires the foam should be played upon the inside of the wall of the container just above the burning surface to permit the natural spread of foam back over the burning liquid, or if this cannot be successfully done the operator should stand far enough away from the fire to allow the foam to fall lightly upon the burning surface. Where possible, the operator should walk around the fire while directing the stream so as to get maximum coverage. For fires in ordinary combustible materials the force of this stream may be used, or the foam may be used to blanket the burning surface according to conditions.

Suitability—These extinguishers are effective either on ordinary Class A fires or on Class B fires. This type of extinguisher is subject to freezing and must be protected where continued temperatures lower than 40 deg. F. will be encountered.

Unit of Installation—One 2½ or 5-gal. or two 1¼ or 1½-gal. extinguishers are considered a unit of first aid fire protection. The 5-gal. size is intended for special use in industrial plants where it may be desirable to have more foam delivered by one extinguisher.

Calcium Chloride (Non-Freezing) Extinguishers

These hand fire extinguishers are usually found in the 2½-gal. size. The extinguishing agent used is a solution of water and a calcium chloride base with important components for avoiding corrosion and/or deposits on operating parts. This solution has a freezing point of 40 deg. F. below zero. The pressure to expel the liquid is produced by a carbon dioxide cartridge.

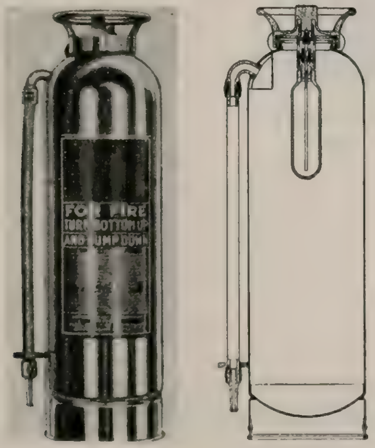
Method of Operation—The extinguisher is carried by means of a top handle and inverted and bumped on the ground to be used. This action expels a stream of extinguishing agent through the hose. While the stream is usually most effective if used close to the fire, in case of necessity it can be directed effectively from a distance of 30 to 40 ft. horizontally.

Suitability—These appliances are best suited for ordinary Class A fires. They are of some use on certain Class B fires, such as in floors soaked with oils, greases, etc., but are not effective on fires in flammable liquids or greases in open containers.

Unit of Installation—One 2½-gal. extinguisher of this type is considered a unit of first aid fire protection.

Loaded Stream Extinguishers

This type of hand fire extinguisher is made in three principal sizes. 1 gal., 1¾ gal. and 2½ gal. The extinguishing agent used is a special solution containing certain alkali metal salts and has a freezing point of 40 deg. F. below zero. The pressure to expel the liquid is produced either by a chemical reaction or by a carbon dioxide cartridge.



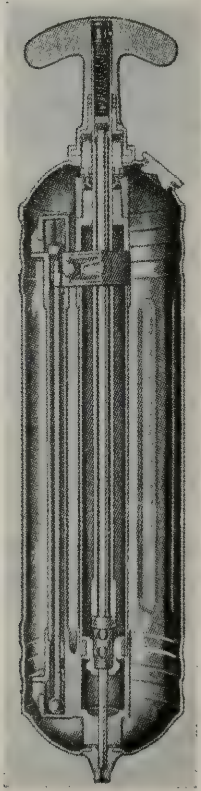
Loaded Stream Extinguishers

Method of Operation—The extinguisher is carried by means of the top handle, and, to be used, must be operated in accordance with instructions which appear prominently on the extinguisher. This action expels a stream of extinguishing agent through the hose. While the stream is usually most effective if used close to the fire, in case of necessity it can be directed effectively from a distance of 30 to 40 ft. horizontally.

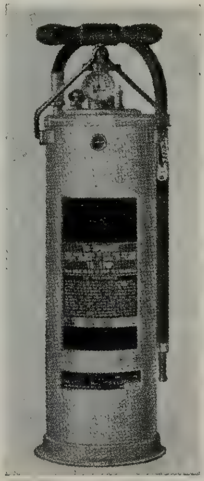
On all fires the stream should be directed at the base of the flames. The extinguishing agent is most effective on fires in flammable liquids in containers when it is not splashed into the burning liquid. For best results it should be played on the wall of the container so as to break up the stream near the burning surface. Where possible the operator should walk around the fire while directing the stream so as to get maximum coverage.

Suitability—These appliances are effective on ordinary Class A fires. They are also effective on certain Class B fires, such as in open vessels or on floors containing small quantities of flammable liquids, greases, etc.

Unit of Installation—One 2½ or 1¾-gal. or two 1-gal. extinguishers are considered a unit for use on Class A fires, while two 2½ or 1¾-gal. or four 1-gal. extinguishers are considered a unit for use on Class B fires.



1 and 1½ Quart



Stored Pressure
1-Gal.

Stored Pressure
1-Gal.

Vaporizing Liquid Extinguishers

Vaporizing Liquid (Carbon Tetrachloride Base) Extinguishers

These hand fire extinguishers are commonly found in 1, 1¼, 1½ and 2-qt. and 1, 2 and 3-gal. sizes. The liquid used in this extinguisher is a special vaporizing non-conducting liquid, consisting of a carbon tetrachloride base with important components added to depress the freezing point to about 40 deg. F. below zero, avoiding corrosion, etc.

Method of Operation—These extinguishers are generally of the hand-pump type. However, some of the larger sizes are of the stored pressure type. The stored pressure type is operated by opening the valve provided on the head castings. The extinguishers are designed to be carried to the fire, and when put into operation, expel a stream of liquid which is vaporized into a smothering vapor by the heat of the fire. While the stream is usually most effective if used close to the fire, in case of necessity it can be directed from a distance of approximately 20 to 30 ft. horizontally.

On all fires the stream should be directed at the base of the flames. This extinguishing agent is most effective on fires in flammable liquids in containers when it is not splashed into the burning liquid. For best results it should be played on the wall of the container so as to break up the stream near the burning surface. Where possible the operator should walk around the fire while directing the stream so as to get maximum coverage.

Suitability—These appliances are effective either on Class B fires or on Class C fires. Carbon tetrachloride vapor has an anaesthetic effect and if subjected to high temperatures decomposes to some extent, forming toxic gases, including hydrochloric acid and phosgene. In using extinguishers of this type, especially in closely confined spaces where ventilation is poor, operators should take precautions to avoid the effects which may be caused by breathing the vapors or gases liberated or produced.

Unit of Installation—Two of any of these extinguishers are considered as a unit for use on Class B fires. One 1, 2, or 3-gal. or two of the smaller sizes are considered as a unit for use on Class C fires. The larger units are intended for use mostly in electrical power plants.

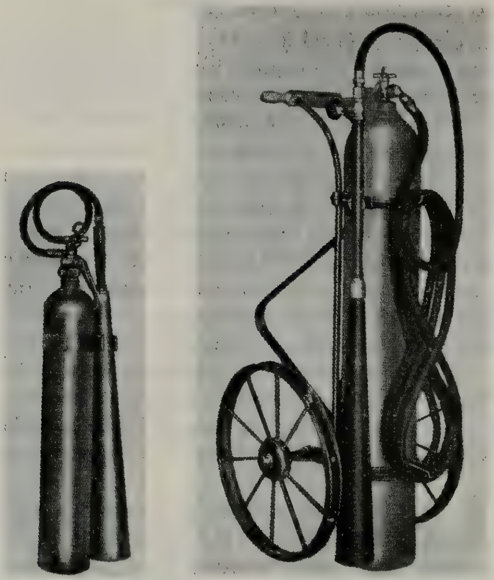
Carbon Dioxide Extinguishers

This type of hand fire extinguisher comes commonly in sizes containing 2, 4, 7½, 10, 15 and 20 lb. of carbon dioxide. The carbon dioxide extinguishing agent is retained under pressure in a liquid condition.

Method of Operation—The extinguisher is carried to the fire by the top handle and to be used must be operated in accordance with instructions which appear prominently on the extinguisher. When put into action this appliance expels a cloud of carbon dioxide gas with some "snow" through the cone. The discharge has a range of approximately eight feet.

Best results are obtained by playing the discharge first at the edge of the base of the fire and gradually progressing forward, moving the discharge horn very slowly from side to side. The discharge should be continued to be directed on the burned substance or surface to deposit carbon dioxide snow even after the fire has been extinguished This will tend to prevent the possible reflash by cooling the hot surface and any glowing material present.

Suitability—These appliances are effective on certain Class B fires, such as in open vessels or on floors containing small quantities of flammable liquids, greases, etc., where the gas may be employed to separate the flames from the burning surface. They are also effective on Class C fires. This type of extinguisher does not need to be protected against freezing.



Carbon Dioxide Extinguishers

Unit of Installation—One 15 or 20-lb. or two 4, 7½ or 10-lb. or four 2-lb. extinguishers are considered as a unit for Class B fires. One 7½, 10, 15 or 20-lb. or two 4-lb. extinguishers are considered as a unit for use on Class C fires.

Dry Chemical Extinguishers

This type of extinguishers is made in sizes having a capacity of 12 and 20 lb. of dry chemicals. The chemical used for the extinguishing agent is a specially treated bicarbonate of soda in dry powder form. A carbon dioxide cartrdige produces the pressure to expel the extinguishing agent.

Pump Tank Extinguishers

These extinguishers are made in two principal sizes, 2½ and 5 gal. The extinguishing agent used is plain water or a non-freezing solution of calcium chloride and water.

Method of Operation—This type of extinguisher is designed to be carried to the fire by means of the top handle and, when used, is operated by a hand pump. This action expels a stream through a hose. While the stream is usually most effective if used close to the fire, in case of necessity it can be directed from a distance of 30 to 40 ft. horizontally.

Suitability—These appliances are best suited for ordinary Class A fires. They are of some use on certain Class B fires, such as in floors soaked with oils, greases, etc., but are not effective on fires in flammable liquids or greases in open containers.

Unit of Installation—One 5-gal or two 2½-gal. extinguishers of this type are considered a unit of first aid protection. The plain water extinguisher must be protected against freezing.

Water Pails—Cask and Pails—Bucket Tank

These types of fire extinguishers are readily understood. The extinguishing agent used is plain water or a non-freezing solution of water and calcium chloride.

Pump Tank Extinguishers

5-Gal. and 2½-Gal.

Suitability—These appliances are best suited for ordinary Class A fires. They are of some use on certain Class B fires, such as in floors soaked with oils, greases, etc., but are not effective on fires in flammable liquids or greases in open containers.

Unit of Installation—Five filled 12-qt. standard fire pails, or one 50-gal. cask with three standard fire pails, or one 25, 35, or 40-gal. bucket tank with at least six 10-qt. standard fire pails.

Fire Pail, Capacity
10 to 14 Quarts

Bucket Tank—Capacity
25 to 40 Gallons

Sand Fire Pails

Sand pails are filled with fine, dry, clean sand, free from gravel, clay or other foreign substance (lake sand preferred). Each pail is provided with a scoop for applying the sand to the fire.

Suitability—These appliances are best suited for certain Class B fires, such as on floors covered with small quantities of flammable liquids and greases, but are not effective on fires in such material in open containers.

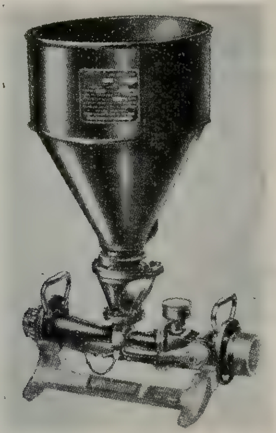
Unit of Installation—Sand pails are not intended for use alone but in connection with other type extinguishers. Five 12-qt. capacity pails are considered as a unit.

Hand Hose

In buildings, having standpipes and an adequate water supply, hand hose may be a useful first-aid fire appliance, as it can provide an extinguishing stream of greater range and capacity than the ordinary extinguishers. A hand hose set consists generally of 50 ft. of 1½-inch hose with ⅜-in. or ½-in. nozzles. The hose is kept attached to the standpipe. For small buildings, the ordinary garden hose makes a good first-aid fire appliance if kept in a convenient place ready for use.

Foam Generators

Portable foam generators are effective weapons of defense against fire hazards of large quantities of inflammable liquids in storage, such as barrel or bulk storage, at oil houses and sumps on oil burning railroads. By means of a foam generator, a mixture of dry foam producing chemicals (foam generating powder) is introduced into a water stream to produce a large sized and sustained stream of fire-smothering foam.



Foam Generator

The generator is put into operation by connecting it into a hose line leading from a hydrant or other source of water supply and attaching 100 or 150 ft. of 2½-in. hose with a 1¾-in. nozzle tip or 1½-in. hose with a 1¼-in. nozzle tip to the outlet connection on the generator. For effective operation the water supply must have at least a pressure of 50 lb. per sq. in. at the inlet of the generator. The fire extinguishing capacity is limited only by the amount of the dry chemicals available and the water supply.

Wheeled Extinguishers

Large units of the soda acid, calcium chloride, loaded stream and foam type are provided for use where such devices are needed. The common sizes for these devices are 17 and 33 gal. Large carbon dioxide and dry chemical units are also available. The common sizes of these extinguishers are 50, 75 and 100 lb. in the carbon dioxide type and 100, 150 and 300 lb. in the dry chemical type.

These wheeled type units have practically the same extinguishing characteristics as the hand type units. The main difference between the wheeled type and the hand type units is in the larger capacity and a longer period of discharge. Care must be taken in considering these devices to see that doorways are wide enough to permit passage of the extinguisher from one room or section to another.

Maintenance—General

Recharging—Recharging immediately after use is important in all types of extinguishers. The chemical reaction types, such as soda acid, foam and certain calcium chloride and loaded-stream extinguishers should be recharged annually. Before recharging, all parts must be thoroughly washed with water.

The vaporizing extinguishers should be partially discharged and refilled annually. No liquid other than that furnished by the manufacturer should be used either for washing or filling. Water will render the extinguisher inoperative in a very short time.

The carbon dioxide extinguishers and certain calcium chloride and loaded-stream extinguishers employing slow-burning cartridges or carbon dioxide cartridges do not have to be recharged annually. Examining the fuse cartridges and reweighing the carbon dioxide cartridges and extinguishers is the only method of determining whether or not they are fully charged. All charging shall be done in accordance with the directions on the extinguisher or as prescribed by the manufacturer of the appliance.

Inspection—All extinguishers should be examined frequently to make sure that they have not been tampered with or removed from their designated places or injured, also to see that they are kept full at all times. Nozzles should be examined to make sure that they are not clogged. It is considered a good practice to operate the pump on the pump-tank extinguisher and discharge the contents back into the container at least once a month. This practice will keep the pump in a free and easy operating condition.

At least once yearly all extinguishers should be inspected thoroughly. Any defects found should be repaired or replaced. The cartridges should be removed and examined and the carbon dioxide cartridges and carbon dioxide extinguishers accurately weighed and checked against the weight stamped on the cartridge or extinguisher or as specified by the manufacturer to determine whether or not the cartridge should be replaced.

On occasions when fire extinguishers of any type are recharged, they should be operated as if at a fire, and employees located near them should be made familiar with their handling and use. A tag should be placed on the extinguishers showing the date of recharge or inspection and the signature of the person doing it.

Non-Freezing Solutions

Appliances such as water pails, casks, drums, bucket tanks, pump tanks, etc. may be used under freezing conditions by employing a non-freezing solution in place of plain water. Calcium chloride is recommended for making this solution rather than common salt, as salt crystallizes in an objectionable manner. Calcium chloride has an affinity for moisture, absorbing it from the air and, retaining it, retards evaporation. The table shows approximately the temperature at which water will freeze when granulated or flake calcium chloride (free from magnesium chloride) is added and thoroughly mixed with it in the proportions shown:

WORKING TABLES FOR MAKING 2½ GAL. OF ANTI-FREEZE SOLUTIONS

Freezing Temp. deg. F.	*Water*	*Calcium Chloride*	*Specific Gravity*	*Degrees Baume*
10	2 gal. 1 qt.	5 lb.	1.139	17.7
Zero	2 gal. 1 pt.	6 lb. 4 oz.	1.175	21.6
–10	2 gal.	7 lb. 6 oz.	1.205	24.7
–20	2 gal.	8 lb. 6 oz.	1.228	26.9
–30	2 gal.	9 lb. 2 oz.	1 246	28.6
–40	2 gal.	10 lb.	1.263	30.2

Note: This table is based on granulated 75 percent calcium chloride.

When these appliances are placed outdoors it is very important that covers are arranged to keep rain and snow from entering the containers and diluting the anti-freeze solution.

Underwriters' Laboratories Label

To the purchaser the Underwriters' Laboratories Label is a guarantee that the extinguisher is effective upon the fires for which it is designed.

This report is submitted as information.

Appendix G

(9) Use and Application of Chemicals for Preventing Deposit in Pipe Lines

R. M. Stimmel (chairman, subcommittee), R. C. Bardwell, W. M. Barr, R. W. Chorley, W. L. Curtiss, R. N. Foster, C. R. Knowles, H. M. Laudemann, J. J. Laudig, Ray McBrian, W. A. Radspinner, D. A. Steel, I. B. Tanner, R. E. Wachter, J. B. Wesley.

One of the difficulties frequently encountered in the distribution and use of water on railroads is with deposits or incrustation in pipe lines, pumps, feedwater heaters, cooling coils, etc. In the Proceedings of the American Railway Engineering Association, Vol. 30, page 154, is a study and report on incrustation in pipe lines and methods for prevention, particularly in treated water. This report mentions the use of carbon dioxide gas, which is not applicable to railroad practice and may be disadvantageous; zeolite softening; the complete treatment of water to a low residual hardness; and the use of certain extracts of the tannin type. Since the publication of the report a new class of chemical substances, molecularly dehydrated phosphates, has been applied to the problem and the use of tannin extracts has been extended.

Incrustation may occur from raw water, completely treated water, or internally treated water. In any case, "lining up" conditions are usually aggravated by higher temperatures. Most of the deposits from raw water on railroads are found where the calcium carbonate content of the water is high, especially if the free CO_2 is low; where the suspended matter is high; or when the water contains large amounts of iron and manganese. Certain micro-organisms, such as crenothrix, may cause troublesome deposits. Incrustation from high calcium hardness may be prevented by aeration or tannin extracts.

The precipitation of calcium carbonate in heaters, cooling coils, etc., from the decomposition of bicarbonates under heat may be prevented in many cases by the use of tannins or molecularly dehydrated phosphates. Iron may be removed by aeration, and crenothrix by chlorination or an algicide. All these substances are largely removed from water by the lime-soda ash type treatment.

The amount of deposition occurring, when completely treated water is used, is usually a function of the amount of calcium carbonate in the water leaving the plant. Incrustation trouble from softened water may be reduced materially by the use of a coagulant, such as sodium aluminate, to produce a water with low residual hardness. It has been reported in the Proceedings of the American Railway Engineering Association that troubles with "liming up" may be reduced materially if the hardness of the softened water is maintained well below one grain per U. S. gallon. If deposits do occur, one of the higher phosphates or a tannin extract may be used.

Probably the greatest source of trouble with deposits in pipe lines, etc., on railroads, is partially treated water, that is, the commonly termed internally treated water. With this type of treatment the hardness of the water is not reduced materially in the plant or tank but is in an unstable condition and after-precipitation may occur. Again, the amount of incrustation usually depends on the calcium carbonate hardness, but magnesium silicate or other substances may be found. Both molecularly dehydrated phosphates and tannin extracts have been used to reduce the amount of substance adhering to the pipes.

The molecularly dehydrated phosphates, referred to above, were discovered about a century ago but were not used commercially or in water treatment until within the last decade. These phosphates are formed by the action of heat, under certain conditions, on mono-sodium phosphates, on disodium phosphate, on a mixture of the two, or on phosphoric acid and soda ash. Water of composition is removed by the process and tetrasodium phosphate, sodium metaphosphate, or some one of the so-called polyphosphates is formed. By sudden chilling after heating, polymerized forms, such as sodium hexametaphosphate, are obtained. All these phosphates are reported to have the property of inhibiting the precipitation of calcium carbonate, but some are decidedly more effective than others.

The following information, covering the use of molecularly dehydrated phosphates, refers specifically to sodium hexametaphosphate, which appears to be the form principally used in the railroad field and is one of the most effective for the prevention of incrustation. The amount of this material which should be used, varies between one and five parts per million. For softened water or for water relatively low in hardness, one to two parts per million is usually adequate. One part per million is equivalent to one pound per 120,000 gal. of water. When the hardness is above 10 grains per gallon, a charge up to five ppm. may be required. The maximum effectiveness is at five ppm. so that heavier charges are useless and might cause trouble. Sodium hexametaphosphate should not be used through the complete treating plant but should be introduced into the water as it leaves the plant. However, it may be used in the vat with soda ash as used for internal treatment. The phosphate decreases in effectiveness at increased temperatures but is reported as still active for several seconds at or slightly above the temperature of boiling water. Sodium hexametaphosphate is not only useful for preventing incrustation but may remove old deposits. Molecularly dehydrated phosphates may be used for preventing incrustation in water that is to be used for drinking purposes as they do not affect the quality of water from that standpoint.

Extracts of the tannin type are probably the most widely used of the substances inhibiting incrustation in pipe lines, etc. It is claimed that the action of this material is physical in cold but may be chemical in hot water. The dosages required will depend on the type of tannin extract used, on the hardness of the water, and on the point of application. It appears that the charge required will vary between one pound per 4,000 and one pound per 8,000 gal. of internally treated water, and between one pound per 10,000 and one pound per 15,000 gal. of completely treated water. An undercharge may be of some benefit and an overcharge will probably remove old deposits. The action of tannins in hot water, such as in feedwater heaters, appears to be improved when there are "soaking periods", especially under heat. Among the advantages claimed for this type of substance for the prevention of incrustation are that its effective limits are not narrow, and its action is less affected by heat. Also, tannins may serve other purposes in some cases, such as oxygen absorption and sludge conditioning.

It is concluded that it is usually possible and generally more economical, to prevent incrustation chemically than to clean or renew pipe lines, etc., periodically. In completely treated water, incrustation troubles may usually be reduced materially through the use of a coagulant, such as sodium aluminate, to produce a water low in residual hardness. It may be advantageous to use a molecularly dehydrated phosphate or a tannin extract. These last two substances may frequently be used to advantage in internally treated water. The determination of the substance to be used and of the charge required to prevent incrustation will vary with local conditions, and formulas cannot be given which will be all inclusive.

This report is offered as information.

Report of Committee 14—Yards and Terminals

Hadley Baldwin, *Chairman,*
J. R. W. Ambrose
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John E. Armstrong
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E. E. R. Tratman
H. L. Vandament
E. P. Vroome
W. J. Yearsley
Committee.

To the American Railway Engineering Association:

Your committee respectfully presents its report on the following assignments:

1. Revision of Manual (Appendix A). It is recommended that the definitions appearing under Appendix A be adopted for publication in the Manual.

2. Requirements in terminal facilities for various later types of equipment. Progress in study—no report.

3. Auxiliary yard facilities and appurtenances—wheel and truck handling equipment for coach yards (Appendix B). Progress report.

4. Scales used in railway service (Appendix C). It is recommended that the material appearing under Appendix C be adopted for publication in the Manual.

5. Substitution of outlying yards and facilities for yards and other large facilities in cities where land values are high (Appendix D). Progress report.

6. Classification yards, collaborating with Committee 16—Economics of Railway Location and Operation. Progress in study—no report.

7. Bibliography on subjects pertaining to yards and terminals appearing in current periodicals (Appendix E). Progress report.

The Committee on Yards and Terminals,
Hadley Baldwin, *Chairman.*

Appendix A

(1) Revision of Manual

L. L. Lyford (chairman, subcommittee), Hadley Baldwin, W. F. Cummings, F. T. Darrow, C. H. Mottier, M. J. J. Harrison, W. H. Giles, G. F. Hand, E. E. R. Tratman.

It is recommended that the following definitions be adopted for publication in the Manual:

Car Retarder.—A braking device, usually power-operated, built into a railway track to reduce the speed of cars by means of brake-shoes which, when set in braking position, press against the sides of the lower portions of the wheels.

Escalator.—One manufacturer's trade-mark for its moving stairway.

Moving Stairway.—A series of steps, attached to an inclined moving mechanism of the endless chain type, leveling out to meet the floor surface at each end, so that a person stepping on is carried from one elevation to another.

Zone Yard.—An auxiliary yard for assembling freight cars destined to or from tracks located in a certain territory.

Bulletin 414, December, 1939.

Appendix B

(3) Auxiliary Yard Facilities and Appurtenances

C. H. Mottier (chairman, subcommittee), J. R. W. Ambrose, Hadley Baldwin, V. J. Bedell, E. J. Beugler, N. C. L. Brown, H. F. Burch, F. T. Darrow, R. B. Elsworth, J. L. Gressitt, R. J. Hammond, E. M. Hastings, E. T. Johnston, H. C. Lorenz, T. R. Ratcliff, W. B. Rudd, H. L. Vandament, W. J. Yearsley.

Wheel and Truck Handling Equipment for Coach Yards

General

Mounted car wheels are subject to many defects, such as flat spots, worn treads, sharp flanges, defective journels, etc., the repair of which necessitates removal of the axle with its pair of wheels. Axle pulleys or other connections for car lighting and air conditioning also develop defects, most of which require wheel changing. Removal of complete trucks, because of defects, is infrequent as compared to the removal of mounted wheels.

Most coach yards are equipped with facilities to remove and replace pairs of wheels and complete trucks, the character and extent of the facilities provided varying with the amount and character of the work in each particular yard. The customary method of removing an individual pair of wheels is by means of a wheel dropping arrangement. Except in the case of large terminals, pairs of wheels are changed on pneumatically or hydraulically operated wheel-dropping jacks usually equipped with a "V" block to engage the axle. Trucks are usually released by means of hand or power operated jacks that lift the car sufficiently to permit the trucks to be rolled from under it.

Modern Wheel-Changing Equipment

Car axles on modern passenger cars may be equipped with roller bearings and generally have auxiliary devices such as pulleys, gear housings or other connections for car lighting and air conditioning equipment. In many cases old fashioned drop jacks, equipped with "V" blocks, cannot handle this work in a satisfactory manner until the interfering parts have been removed, which involves additional expense in time and labor.

Frequently both the pneumatic and the hydraulic wheel-dropping jacks possess insufficient capacity to raise a pair of wheels above the railed gates or beams spanning the pit to permit the removal of these interfering members preparatory to dropping the wheels. In such cases a pair of auxiliary jacks must be used to raise the car slightly and support the load. In many installations it is necessary to place additional jacks under the truck to raise it slightly and hold it in position while the wheel-dropping jack lowers the pair of wheels.

Modern drop-pit tables greatly simplify the operation, as the rails spanning the pit are a part of the movable table and wheels can be removed, supported on these rails, without any part of the lifting mechanism coming in contact with the axle. This type of equipment preferably should have the following characteristics, for the reasons indicated:

1. Capacity sufficient to raise a pair of wheels above the rails spanning the pit (ordinarily 20 tons), thus eliminating the use of auxiliary jacks and additional equipment.
2. Detachable table tops to engage the wheel treads instead of the axles, so as to avoid having to strip the axles of pulleys or other attachments.

3. Electric operation, to provide a low cost source of power and to permit the use of remote control.
4. Remote control through a pendant switch, to assure safety and to promote efficiency of operation.

Drop-pit tables can be obtained in a wide range of capacities and dimensions. A pit width of 48 in. appears to be about standard. The hoisting speeds range from one to three feet per minute. Tops may be either floored or skeleton, and lifting mechanisms may consist of one, two or four supports. Detachable tops can be locked in position, and can then support a car or switch engine passing over the pit. With two or more detachable table tops, it is practicable to have one pit and one main drop-table mechanism operate under two or more active repair tracks to the wheel-release track, so that two or more operations can be in progress simultaneously. Such an arrangement will greatly expedite the work, as wheels can be changed on a car standing on one track while another car is being moved into position on the adjacent track. For this operation the pit must be of sufficient depth to permit the table carrying a pair of wheels, released on one track, to pass under the other detachable top locked in position under the adjacent active track.

High-Lift Portable Jacks for Wheel Changing

Some roads prefer high-lift portable car jacks for changing wheels. Frequently local conditions dictate which type of equipment is preferable. In some terminals, switching locomotives are used for spotting cars at drop pits, though car pullers are frequently used for that purpose.

Where high-lift portable jacks are used, the cars are switched to a special track and spaced a sufficient distance apart to permit truck replacements. This track has continuous concrete runways and jack supports along both sides, usually at the level of the base of rail and about six feet wide. Two jacks on these platforms are used to raise one end of the car after the truck is lashed to the car sills. As the car is raised, the truck rises with it, leaving the pair of wheels standing on the rails. The jacks may be moved along the platform to serve the different cars, thereby eliminating the use of switch engines or car pullers. An advantage of the jacks is that they can be used to release complete trucks and to do other necessary work. A high lift (three to four feet) is required to raise the car sufficiently to allow the truck to be rolled out from under the steps of the car. At some of the larger terminals both drop pits and high-lift jacks are used,—the former to remove pairs of wheels and the latter to remove trucks.

In recent years some railroads have shown a preference toward electric operation of high-lift portable jacks. This type of operation permits push-button control, and enables the operator to synchronize the hoisting operations of two jacks from a single control station.

High-lift portable jacks should preferably have the following characteristics, for the reasons indicated:

1. Easy portability, to facilitate movement from car to car.
2. Approximately four-feet lift without re-setting of jacks, to assure safety and save time and labor.
3. Ample capacity (25 tons for each jack), to eliminate the necessity for additional jacks.
4. Large bases with loads on the bases instead of on wheels, to assure safety for high lift and to eliminate the need for horses or trestles.

Comparison of Drop Pit Tables and Electric Jacks

Local conditions may create an advantage for one type of equipment as against the other. In some cases, the cost of two jacks with their concrete runways and jack supports would about equal the cost of a drop-pit table and pit. The high-lift jack can be used for truck release, as well as for wheel changing. The jacks, however, must be hauled along the track. Plug-in stations must be provided and cars must be separated and the wheels rolled for some distance (generally with several changes in direction) to storage tracks. The majority of railroads favor the use of drop pits for handling single pairs of wheels at coach yards. Complete trucks can then be removed, as required infrequently, by the usual method of jacking up the car.

Large Four-Support Drop Pit Tables

Drop-pit tables with four supporting screws, electrically driven, are built of sufficient size to remove either four or six-wheel trucks. They can be used also for removing single pairs of wheels. The large table may be constructed with one or two small tables within it, so that the former may be locked in position to support the truck and the car while a small table is lowered with one pair of wheels, thus avoiding the necessity of blocking the car or truck while the single pair of wheels is being removed.

Facilities to Handle Both Diesel-Electric Streamlined and Standard Equipment

In several yards Diesel-electric streamlined trains and standard equipment are accommodated in the same coach yard. There is a definite tendency, however, where a large amount of Diesel-electric equipment is to be handled, to accommodate it in a separate yard having special facilities. If such separate provision is not made, an electrically-operated four-support drop-pit table of sufficient capacity and size to handle complete four-wheel and six-wheel Diesel-electric locomotive trucks and passenger car trucks may be provided.

An overhead short-span crane with a capacity of at least ten tons should span the pit to serve the active track and the release track for helping to dismantle the removed trucks and for lifting parts from the locomotive. Diesel-electric equipment recently constructed has jacking pads located beyond the trucks for supporting the locomotive body on trestles or posts on the ground near the pit walls.

Some railroads giving consideration to the handling of Diesel-electric locomotives in the same yard with coaches have proposed the use of a small electric drop-pit table of the screw type for handling single pairs of wheels, and a shallow-pit type of transfer table to remove the complete trucks of coaches and Diesel-electric locomotives, with the addition of at least two portable high-lift electric jacks. The procedure is to raise one end of the locomotive or car body sufficiently (approximately 12 in.) to clear the center castings, while the truck is standing on the transfer table. After clearance is obtained, the transfer table is racked sidewise to the release track, where the overhead crane can serve the truck. There are certain advantages in such a layout, although the cost would be about the same as for the large size four-screw drop table. The advantage in the use of a small drop-pit table, transfer table and electric portable jacks, lies in the fact that the drop table would be in a different location and could remove numerous single pairs of wheels from cars while the other facilities are handling Diesel-electric trucks.

Auxiliary Facilities

A low narrow transfer car frequently referred to as a "dolly" is very useful in moving wheels between the drop pit and the storage tracks. The dolly track (narrow gage) should be located at the end of the drop pit nearest to the wheel storage tracks.

A hand-operated turntable should be installed at one side of the drop pit at the end adjacent to the dolly track. A pair of released wheels can then be moved from the drop-pit table top to this turntable and turned 90 deg. so they can be rolled onto the dolly with the axle in line with the dolly and the dolly track. The pair of wheels can then be transported on the dolly to any one of the wheel storage tracks. The arrangement of the dolly, the dolly tracks and the wheel-storage tracks should be such that the released wheels need not be raised or lowered in the movement between the drop-pit table and the wheel storage tracks.

Various types of cranes are successfully used to load wheels on freight cars. Movable cranes are also used for that purpose and when not thus engaged are available for other work. In some yards, depressed tracks are used to permit loading wheels by hand.

Under certain climatic conditions, a housing over the drop pit, to protect the equipment and workmen, is desirable.

This report is presented as information.

Appendix C

(4) Scales Used in Railway Service

M. J. J. Harrison (chairman, subcommittee), John E. Armstrong, Hadley Baldwin, H. G. Basquin, W. J. Brennen, E. D. Gordon, E. M. Hastings, H. O. Hem, E. K. Lawrence, H. C. Propst, C. L. Richard, H. M. Roeser, W. C. Sadler, C. U. Smith, E. P. Vroome.

Under this heading, your committee submits proposed revisions of four items of Chapter 14 of the Manual.

Page 14–40:

Maintenance tolerances for application to railway track scales are now stated as follows:

(b) *Maintenance Tolerance.*—The maintenance tolerance on track scales in commercial weighing service shall be—

> 1. Two-tenths of 1 percent, or 2 pounds per 1,000 pounds of test load, when one car of 7-foot wheelbase or less is used, the tolerance to be applied to the largest mean of two errors found for different positions of the test car not closer than similar positions on adjacent spans. In no case shall the error at any position exceed 3/10 of 1 percent, or 3 pounds per 1,000 pounds of test load.
> 2. Two-tenths of 1 percent, or 2 pounds per 1,000 pounds of test load, when two standard test cars are applied on the scale at the same time and at positions not closer together than similar points on adjacent spans.
> 3. Two-tenths of 1 percent, or 2 pounds per 1,000 pounds of test load, when the wheelbase of the test car exceeds 7 feet.
> 4. Two-tenths of 1 percent, or 2 pounds per 1,000 pounds of test load, on two-section scales.

The wording of sub-paragraph 1 of the foregoing excerpt was initially composed before the two-section railway track scale came into general use, and was definitely intended to apply to railway track scales of more than two sections. It is ordinarily so applied; however, a literal reading of this sub-paragraph, in conjunction with sub-paragraph 4 quoted above, discloses a contradiction and inconsistency. It is proposed to correct this inconsistency, and to make the application of the several sub-paragraphs more immediately obvious, without in any way altering the designed import of the material, by revising the entire item to read as follows:

(b) *Maintenance Tolerance.*—The maintenance tolerance on track scales in commercial weighing service shall be—

> 1. On a scale of more than two sections, two-tenths of 1 percent, or 2 pounds per 1,000 pounds of test load, when one test car of 7-foot wheelbase or less is used, the tolerance to be applied to the largest mean of two errors found for different positions of the test car not closer than similar positions on adjacent spans. In no case shall the error at any position exceed three-tenths of 1 percent, or 3 pounds per 1,000 pounds of test load.
> 2. On a scale of more than two sections, two-tenths of 1 percent, or 2 pounds per 1,000 pounds of test load, when two or more test cars of 7-foot wheelbase or less are applied on the scale at the same time and at positions not closer together than similar points on adjacent spans.
> 3. On a scale of two sections, two-tenths of 1 percent, or 2 pounds per 1,000 pounds of test load, for any position of the test car or cars on the scale.
> 4. On any scale, two-tenths of 1 percent, or 2 pounds per 1,000 pounds of test load, for any position of the test car on the scale when the wheelbase of the test car exceeds 7 feet.

Page 14–40:

A special maintenance tolerance is stated for application to railway track scales equipped with automatic recording devices, and two different types of devices are contemplated. One of these types would print a record somewhat as does the ordinary adding machine, and the tolerance requirement was framed on the assumption that the difference between successive indications would be 100 pounds. The requirement now reads:

> 2. If the weight indication is a printed record in figures representing the weight of the applied load to the nearest unit or multiple of the unit of weight, the tolerance shall be that applicable to the scale independent of the automatic device, plus 50 percent of the increment between indications that can be printed by the device.

Devices of the type contemplated would probably be manufactured with a difference between successive indications of 100 pounds, as initially assumed. However, there is nothing to prevent a manufacturer from marketing or attempting to market such a device having a difference between successive indications of, say, 200 pounds. The present wording of the tolerance requirement would permit such a device to be unduly inaccurate. To avoid such a possibility, it is proposed to reword the item so as to require that the additional tolerance allowed on account of the mechanical construction of the device will in no case exceed 50 pounds. The following wording is proposed:

> 2. If the weight indication is printed in Arabic numerals without means for reading said indication more closely than the value of one increment that can be printed by the device, the tolerance shall be that applicable to the scale independent of the recording device, plus 50 percent of the value of one increment, or 50 pounds, whichever value is the smaller.

Page 14–97:

Your committee has received and considered a request from manufacturers of motor truck scales for a slight amendment of paragraph 1306-(a), which relates to the values of notches and graduations on the weighbeams of motor truck scales, and which now reads:

In motor truck scales, the value of each notch on the main bar shall be 1,000 pounds.

Your committee has been requested to recommend that this item be amplified to read:

In motor truck scales, the values of the intervals between successive notches or graduations shall be 1,000 pounds on the main bar, and not more than 10 pounds on the fractional bar, respectively.

Your committee is of the opinion that this rewording in no way affects the original intent of the specifications, and recommends its approval.

Page 14–99:

Table 1410 sets forth the tolerances applicable to new counterpoise weights. The figures shown therein were abstracted from a table formerly promulgated by the National Bureau of Standards and recommended for uniform adoption. The National Bureau of Standards having revised its recommendation, our Manual material should be correspondingly revised in the interest of uniformity. A revised Table 1410 is therefore proposed, as follows:

TABLE 1410

TOLERANCES ON NEW COUNTERPOISE WEIGHTS

(Avoirdupois System)

Weight (pounds)	*Tolerance (grains)*
10	10.0
8	9.0
5	6.5
4	6.0
3	5.0
2	4.0
1	2.5
(ounces)	
10	2.0
8	1.5
5	1.0
4	1.0

Appendix D

(5) Substitution of Outlying Yards and Facilities for Yards and Other Large Facilities in Cities Where Land Values Are High

W. H. Giles (chairman, subcommittee), J. R. W. Ambrose, C. E. Armstrong, C. J. Astrue, W. O. Boessneck, H. F. Burch, F. T. Darrow, J. L. Gressitt, R. J. Hammond, E. M. Hastings, C. H. Mottier, H. L. Ripley, W. C. Sadler, W. J. Yearsley.

Facilities most likely to be considered within the scope of this subject are freight terminals and appurtenances, including locomotive servicing and car repair facilities. This report is limited to the consideration of freight terminals.

A terminal occupies a large area of land and when it is within an inlying section of a city the property investment is considerable, because the land values are usually high. The large area occupied by the terminal and its relative importance in railway operations frequently make this facility the object of serious scrutiny.

The modern trend of the railway industry is toward a method of operation which will provide the maximal service consistent with safety and the class of commodity handled. Faster freight train schedules between metropolitan centers have speeded up the on-line movement and imposed upon the freight terminal the responsibility for improved delivery. As traffic increases the terminal operations become more complex and new methods must be developed to insure continued progress and a balanced system.

With a material increase in traffic or change in business requirements in a specific locality requiring expansion or re-arrangement of the facility and in cases where governmental restrictions are burdensome, studies should be made to develop the most economical and efficient plans for the future.

The study should be made by a committee representing all the parties at interest, including engineering, transportation, mechanical and traffic officers, supported by persons having expert knowledge of the various phases of the problem. A complete analysis should be made to develop the facts with respect to the existing facility; including its design as effecting expedition and economy in use, operation and maintenance; consulting freely with those charged with administration regarding traffic handled, method of operation, unusual economical or uneconomical features and operating schedules affected. The study should not be limited to the immediate terminal facility but should include facilities and method of operation at intermediate terminals and division points as well as on-line operation and schedules.

In digesting properly the situation at any terminal, care must be taken to distinguish between the physical disabilities, including faulty design or insufficient capacity, and inefficient operation and allied functions which result in failure to clear the yards promptly when cars are ready to move. In the latter case the difficulty may be attributable to inadequate main line capacity, lack of sufficient and efficiently serviced motive power, or inefficient terminal generalship and performance.

Where the availability of efficient road power and crews is constantly synchronized with a terminal's classification and assembly achievements, a minimal congestion and car detention should result.

In general, the expansion or relocation of a terminal for the sole purpose of providing additional trackage for the storage of cars ready for forwarding is not justified.

When the conditions underlying the consideration of a change in location are not involved with governmental restrictions and legal requirement and the problem can be analyzed strictly from the point of view of economical and satisfactory railway operation, all factors should be weighed in accordance with their relative significance, keeping in mind the fundamental principal of terminal operation that each time a car is transferred from one unit to another in its movement through a terminal, unavoidable accruals of detention and expense are invariably the result.

Where the location of the inlying terminal is such that receipts and deliveries to and from industries and connections can be handled expeditiously, any scheme to locate the facilities at an outlying point should be approached with caution, and unless some change in primary operations is made a part of the terminal plan and the arrangement is obviously logical and advantageous to the extent that other inherent disadvantages are outweighed, a complete study should be made.

Some of the reasons for making a change in the facilities include:

1. Obsolescence or inadequacy.
2. Consolidation of separate facilities (such as engine terminal and train yard).
3. Readjustment or consolidation of mechanical repair and maintenance facilities and forces on a division or district.
4. Consolidation of the operations of several small inlying yards in a new facility and confining the small yards to zone switching operations.
5. Co-ordination with other railways.
6. Delays to road trains.
7. Delays to switching movements.
8. Delay in interchange.

9. Change in method of operation.
10. Public body regulations.
    (a) Switching restricted to certain periods during day.
    (b) Street and railway crossings.
    (c) Grade separations.
    (d) Smoke abatement.

In the final analysis a conclusion must be based upon an evaluation of the determining factors entering into the consideration of the subject. These factors may be considered in the form of tangible or intangible advantages and disadvantages in the order of their importance.

Some things to be considered in developing plans for a new facility include:

1. Service to shipper and consignee.
2. Ratio of fast trains to slow trains handled.
3. Possible delays at outlying facility and extra handling of cars.
4. Increased switching at outlying facility—
    (a) for local business.
    (b) to reduce switching at on-line terminals or division points.
5. Possible readjustment of road train schedules.
6. Curtailment of operations at inlying facility by doing work at some other place.
7. Limiting facility to normal requirements (not peak load) with provision for nominal future expansion. (This will result in increased operating cost during peak load).
8. Limiting traffic in inlying facility to that requiring preferred handling and run fast trains direct.
9. Careful and complete determination of operating procedure for new out-lying facility is essential to complete analysis.
10. Complete diagnosis to determine whether some exterior condition is responsible for or contributes to the inadequacy of inlying facility; such as inefficiency and unreliability of road power and switch power, quality and quantity of water fuel supplies, capacities of main lines and arrangement of facilities.

Abandonment of an inlying facility may release property which can be utilized for other purposes; including industrial development, team tracks, interchange yard, repair facilities or as a zone yard for handling local traffic. Generally these incidental factors are considered of secondary importance.

In conclusion it may be stated that many railways have considered the construction of outlying terminals in substitution for or to supplement inlying yards. For various reasons the change has not been made in some cases. In other cases the new facility has been provided and then permanently or temporarily discontinued and operations resumed in the old inlying facility. In most cases, where the new facility is being operated, the service to local shippers has been improved, traffic through the terminal has been expedited and, in general, the change is considered justified, although the anticipated reduction in unit costs may not have been realized.

Some possible advantages of new outlying facilities are:

1. Consolidation of forces.
2. Improved interchange.
3. Reduction in road train time.

4. Better classification of outbound road trains, thereby reducing amount of switching at intermediate terminals and division points.
5. New facilities are modern and result in economies through efficiency.
6. Potential value of space occupied by inlying facility for industrial sites and other purposes.

Some possible disadvantages of new outlying facilities are:

1. Cost of the facility.
2. Increase in delivery time.
3. Increased local switching and transfer movement.
4. Necessity for increased classification at intermediate terminals and division points, to block inbound trains for faster terminal distribution.
5. Traffic loss account delay of small amount of traffic, affecting a particular industry's business and penalizing by that industry at other points.

Offered as information with recommendation that subject be discontinued.

Appendix E

(7) Bibliography on Subjects Pertaining to Yards and Terminals

E. E. R. Tratman, Chairman, Subcommittee

General

Buildings—Air conditioning; passenger and office buildings; also fruit and produce storage and ripening; temperatures and humidity—AREA, Proceedings, 1939, pages 198, 200.

Buildings—Air conditioning; Union Pacific Railroad office building at Omaha, Neb.—Railway Age, 1939, July 29, page 170.

Buildings—Air-right developments; form of lease—AREA, Proceedings, 1939, page 725.

Buildings—Delaware, Lackawanna & Western Railroad removes many old buildings to save taxes and maintenance—Railway Age, 1939, June 10, page 989.

Buildings—Fire protection equipment; hose and nozzle design—AREA, Proceedings, 1939, pages 232 and 754.

Buildings—Insulation of roofs, walls, floors, etc., in passenger stations and freight houses; Baltimore & Ohio Railroad—Railway Age, 1939, April 15, page 656.

Buildings—Platforms and floors in passenger and freight buildings (wood, concrete, brick, bituminous)—AREA, Proceedings, 1939, pages 196 and 211.

Buildings—Prevention of damage by termites—AREA, Proceedings, 1939, page 505.

Car Loadings—Standard rules for freight car loading—Mechanical Division (AAR), Proceedings, 1939.—Railway Age, 1939, July 1, page 26.

Co-ordination of Transport—Chicago, Burlington & Quincy Railroad; bus and truck routes—Railway Age, 1939, May 27, page 913.

Co-ordination of Transport—French National Railways Company; co-ordination equivalent to great annual savings—Railway Gazette (London), 1939; March 7, page 597.

Co-ordination of Transport—Gulf, Mobile & Northern Railway; bus and truck service—Railway Age, 1939, November 12, page 713.

Co-ordination of Transport—Illinois Central Railroad; containers on flat cars and truck-trailers handle L.C.L. traffic on routes radiating from DuQuoin and Carbondale, Ill.—Railway Age, 1939, September 23, page 447; Business Week, 1939, July 1, page 20.

Co-ordination of Transport—India; control and regulation of motor highway transport—Railway Gazette (London), 1939, September 22, page 399.

Co-ordination of Transport—London & Northeastern Railway (England); road transport for freight and live-stock—Railway Gazette (London), 1938, September 23, page 525.

Co-ordination of Transport—Nigerian Government Railways; Railway Gazette (London), 1939, April 7, page 584.

Co-ordination of Transport—South Australian Government Railways; report of special commission on Board of Transportation Control—Railway Gazette (London), 1939, April 7, page 572.

Co-ordination of Transport—Rock Island Lines; truck service—Railway Age, 1938, December 31, page 956.

Co-ordination of Transport—St. Louis, Mo.; terminal interchange by Columbia Terminals Company—Western Railway Club, Proceedings, 1939—Railway Age, 1939, May 20, page 878.

Co-ordination of Transport—St. Louis Southwestern Railway; rail and truck service—Western Railway Club, Proceedings, 1939—Railway Age, 1939, May 13, page 829.

Co-ordination of Transport—Southern Pacific Transportation Company in Texas; truck operation in connection with train services—Railway Age, 1939, July 15, page 117.

Co-ordination of Transport—Swedish State Railways and post office; passenger and mail service by busses and motor trucks—Railway Gazette (London), 1938, September 23, page 529.

Co-ordination of Transport—Texas & Pacific Railway; rail and road service in Louisiana—Railway Age, 1938, September 24, page 452.

Co-ordination of Transport—Motor carriers subject to Interstate Commerce Commission—Railway Age, 1939, September 2, page 350.

Co-ordination of Transport—Review of railway bus and motor truck service in 1938—Railway Age, 1939, January 7, page 93; July 22, page 143.

Co-ordination of Transport—Railway and highway traffic in co-operation; address by C. E. Johnston—AREA, Proceedings, 1939, page 62.

High-Speed Freight Service—Pennsylvania Railroad experiments—Railway Age, 1939, July 8, page 70.

Stopping Trains—Determination of cost. Report on study, including charts and formulas—AREA, Proceedings, 1939, pages 182 and 722; Railway Age, 1939, April 22, page 687; Signal Section (AAR), Proceedings, 1939, No. 1, Volume 36, page 6.

Terminal Bonds—Bond issues of Cincinnati Terminal Company and St. Louis Terminal Railroad—Railway Age, 1939, July 15, page 123.

Terminals—Modernizing and reconstruction of stations, storehouses, engine terminals, etc.—American Bridge and Building Association, Proceedings, 1938, page 61—Railway Age, 1939, January 7 and July 22, page 27 and 132—Railway Engineering and Maintenance, 1938, November.

Passenger Stations and Terminals

Algiers, Africa—New central station convenient to steamship landing quay—Railway Gazette (London), 1938, September 23, page 518.

Apsley, England—London, Midland & Scottish Railway; heavy train and passenger traffic; concrete platform shelters; bituminous platforms with concrete curbs—Railway Gazette (London), 1938, September 30, page 567.

Birmingham, England—Great Western Railway; new Snow Hill station and hotel (pictures only)—Railway Gazette (London), 1939, May 26, page 867.

Blackpool, England—London, Midland & Scottish Railway; concourse roof of concrete rigid-frame arches 62 ft. span, 40 ft. apart, with concrete beams to carry roofing and skylights. Reconstruction of Central Station on new site with air-right developments—Railway Gazette (London), 1938, November 25, pages 907–911; 1939, June 16, page 1000.

Bruges and Ostend, Belgium—Relocation through Bruges, with new 10-track station. Old station at Ostend abandoned for enlarged Quay Station, 10 platforms and platform tracks—Railway Gazette (London), 1939, April 28, page 691.

Budapest, Hungary—Theoretical analysis of problems of train service and passenger accommodation, etc. Paper by Dr. Ing A. Patz, director, Budapest Railways—International Congress of Light Railways and Tramways, Proceedings of meeting at Zurich, 1939.

Budapest, Hungary—Proposed rearrangement of terminals and lines, with new station and 3-mile tunnel under Danube River—Railway Gazette (London), 1939, July 14, page 51.

Buenos Aires, Argentina—Retiro Station, Argentine State Railways; picture only, showing oil-engine trains and rail cars for suburban service—Railway Gazette (London), 1939, September 29, page 150 (supplement).

Chessington, England—Southern Railway; suburban terminal; concrete cantilever platform roofs—Railway Gazette (London), 1939.

Chicago, Illinois—Chicago & Northwestern Railway; renewing longitudinal timbers which carry rails in the terminal station—Railway Engineering and Maintenance, 1939, September, page 526.

Chicago, Illinois—LaSalle Street Station, Rock Island Lines and New York Central Lines; track reconstruction with concrete floor and wood blocks for the rails—"Concrete for Railways" (bulletin of Portland Cement Association), October, 1939, Vol. 3, No. 3.

Chicago, Illinois—Rapid-transit subway stations—Western Society of Engineers, Proceedings, 1938, December, page 289.

Chicago, Illinois—Union Pacific Railroad; new city ticket office—Architectural Record, 1939, March, page 51.

Copenhagen, Denmark—Electrification and extension of municipal Copenhagen—Slangerup suburban line to new central station—Railway Gazette (London), 1939, September 15, page 371.

Country Stations—Great Western Railway (England); designs made to harmonize with local rural architecture—Railway Gazette (London), 1938, December 23, page 1098.

Dartmouth, New Hampshire—Colonial architectural design for station of Boston and Maine Railroad and Vermont Central Railroad—Railway Age, 1938, September 17, page 401.

Edinburgh, Scotland—Photographs of Waverly Station in 1850 and 1939; London, Midland & Scottish Railway—Railway Gazette (London), 1939, August 11, pages 214 and 219.

English Railways—Architectural design of English railway stations; paper by Professor Richardson—Railway Gazette (London), 1939, April 28, pages 677 and 683.

Frankfort, Germany—Jubilee of present handsome station, opened in 1888—Railway Gazette, (London), 1938, September 30, page 574.

Genoa, Italy—Enlargement of Central Station; ten approach tracks in four tunnels (1:2:4:2:1)—Railway Gazette (London), 1939, June 2, page 894.

Kampala, Africa—Northern terminal of Kenya & Uganda Railway (pictures only)—Railway Gazette (London), 1939, June 2, page 898.

London, England—Southern Railway; private passenger station for Imperial Airways Company on short branch line—Railway Gazette (London), 1939, June 9, page 943.

London, England—Euston Terminal Station; London, Midland & Scottish Railway; layout plan and photographs—Railway Gazette (London), 1938, September 16, page 11 (Supplement).

London, England—King's Cross terminal station; London & Northeastern Railway; modernization of facilities; separate suburban station—Railway Gazette (London), 1939, June 9, page 947.

London, England—King's Cross underground station; London Passenger Transport System; complicated tunnels and junctions; escalators move 125 ft. per minute, or 165 to 180 ft. during rush hours—Railway Gazette (London), 1939, June 23, page 1006.

London, England—Liverpool Street terminal station; London & Northeastern Railway; modernizing, cleaning and lighting—Railway Gazette (London), 1939, April 21, page 656.

London, England—Traffic at terminal stations; 4,217 trains and 1,300,000 passengers arrive daily; maximum number of passengers, 209,000 at Liverpool Street; maximum number of trains, 1,424 at Waterloo (711 inbound)—Railway Gazette (London), 1938, November 11, page 808.

London, England—Underground Railways; reconstruction of Mile End Road station; 55,000,000 passengers annually; 11,000,000 change trains here—Railway Gazette (London), 1939, April 21, page 665.

London, England—Underground Railways; Moorgate Street station; connecting two stations on separate lines for passengers to transfer without going to the surface—The Engineer (London), 1938, October 7, page 380.

London, England—Victoria terminal station; Southern Railway; aerial view of approach lines—Railway Gazette (London), 1939, July 28, page 149—Resignalling arrangements; station in two sections; 18 tracks (pairs and triples); two approaches with four and five tracks—Railway Gazette (London), 1938, October 21, page 681; 1939, June 30, page 1063.

Los Angeles, California—Union Terminal Station, $11,000,000; Atchison, Topeka & Santa Fe Railway; Southern Pacific Railway and Union Pacific Railway; passenger ramps 7 percent grade—Engineering News-Record, 1939, May 4, page 625—Railway Age, 1939, May 6, page 768; September 9, page 367—Concrete for Railways (bulletin of Portland Cement Association), 1939, Vol. 3, No. 3, October—Southern Pacific Bulletin, 1939, June, July and August.

Mehsana, India—Layout and new signal system for station and passing sidings; Bombay, Baroda & Central India Railway—Railway Gazette (London), 1939, September 29, page 431.

Milwaukee, Wisconsin—Chicago, Milwaukee, St. Paul and Pacific Railroad; new roof on steel truss trainshed, 92 ft. span—Railway Engineering and Maintenance, 1939, August, page 472.

Mainz, Germany—Arch trainshed roof of Central Station, built in 1884, 138 ft. wide, 984 ft. long, to be replaced by platform shelters—Railway Gazette (London), 1938, October 21, page 706.

Manhattan, Kansas—Rock Island Lines; modernizing the station in a town of 10,000—Railway Engineering and Maintenance, 1939, February, page 84.

Montreal, Canada—Canadian National Railways; renewal of work on new terminal—Canadian Transportation, 1939, January and April, pages 28 and 161—Railway Age, 1939, February 11, page 260—Engineering News-Record, 1939, October 19, page 513.

Mulhouse, France—New station; 11 tracks, 6 platforms, concrete umbrella sheds—Railway Gazette (London), 1939, June 9, page 944.

Newcastle, England—London & Northeastern Railway; complicated crossing and junction of two four-track lines—Railway Gazette (London), 1938, November 18, page 864.

New York, New York—Pennsylvania Railroad terminals—Railway Age, 1939, July 8, page 86—"Fortune", 1939, July.

New York, New York—World's Fair station, Long Island Railroad; traffic studies and 7-track station for shuttle trains of 12 cars on 2-minute headway to and from Pennsylvania Railroad terminal; to handle 20,000 passengers per hour—Engineering News-Record, 1938, September 22, page 381—Railway Age, 1938, November 26, page 766; 1939, May 13 and 27; June 3 and 10; pages 823, 905, 937 and 984.

Paris, France—French National Railways Company; Montparnasse terminal to be rebuilt on new site—Railway Gazette (London), 1939, September 8, page 344.

Rome, Italy—Reconstruction of Termini Station, and building of four new stations for local and freight traffic, to be completed in time for 1942 Exhibition. New Termini Station; 22 platform tracks in pairs, 12 platforms; station building four stories above and three below rail level—Railway Gazette (London), 1939, June 23, pages 686 and 1015.

San Francisco, California—Terminal for San Francisco-Oakland suburban traffic over Bay Bridge; traffic peak-hour, 14,000 passengers, 95 trains outbound; ramps of 10 percent grade and stairways serve platforms—Architectural Record, 1939, July, page 31—California Highways and Public Works, 1937, March and August, pages 17 and 26—Railway Age, 1939, May 13, page 815—Railway Gazette (London), 1939, September 15, page 102 (Supplement).

San Francisco, California—Traffic studies and terminal design for World's Fair—Engineering News-Record, 1938, October 13, page 472.

Strasburg, France—French National Railways Company; new power signalling—Railway Gazette (London), 1939, September 1, page 323.

Sydney, New South Wales—Underground rapid-transit railway and new station—Railway Gazette (London), 1939, September 29, page 427.

Tokyo, Japan—Central station needs enlargement on account of traffic congestion; rush period, 30,000 per hour; daily average 350,000 passengers—Railway Gazette (London), 1939, July 7, page 36.

Uxbridge, England—New terminal for London Passenger Transport Board's suburban system; three stub tracks; loop driveway keeps vehicles clear of street traffic. Bus station at one side—Railway Gazette (London), 1938, December 2, page 968.

Wellington, New Zealand—Enlargement of station on earthquake-proof foundations. Booklet issued by New Zealand Government Railways—Railway Gazette (London), 1939, April 7, page 577 and August 11, page 207.

Weymouth, England—Reconstruction of station having heavy resort traffic; 20 trains in and 20 out daily, with 17,000 passengers—Railway Gazette (London), 1939, September 8, page 353.

Zurich, Switzerland—Swiss Federal Railways; signal in trainshed to order enginemen of entering trains to make brake test—Railway Gazette (London), 1939, August 11, page 213.

Bus Garage—Toronto Transport Commission; building 374 ft. long; steel roof, repair pits—Canadian Transportation, 1938, September and October, pages 460 and 525.

Bus Service—Train and bus travel on U. S. railways—Railway Age, 1939, January 7 and May 13, pages 94 and 817.

Bus Service—Train connections for Los Angeles suburban district; Union Pacific Railroad Railway Age, 1938, September 10, page 380.

Bus Service—At French Lick Springs; Chicago, Indianapolis & Louisville Railroad—Railway Age, 1939, March 4, page 383.

Bus Service—Missouri Pacific Railway; experience satisfactory—Railway Age, 1939, February 4, page 230.

Bus Service—New York, Susquehanna & Western Railroad; busses between North Bergen station and Times Square, New York, improve commuter service—Railway Age, 1939, August 5, page 217.

Bus Stations—Missouri Pacific Railway, at Little Rock, Ark.; center of numerous routes —Railway Age, 1939, July 8, page 78.

Bus Stations—Designs used by London Passenger Transport Board—Railway Gazette (London), 1939, June 23, page 1031; July 28, page 143.

Bus Terminal—At Los Angeles, California, for bus lines of the Burlington and Santa Fe Railways—Railway Age, 1939, August 12, page 260.

Coach Yards—Chicago & Eastern Illinois Railway at Danville, Illinois; steel, brick and glass block building served by transfer table; cars lifted by portable jacks—Railway Mechanical Engineer, 1939, September, page 364.

Coach Yards—Great Western Railway, at Paddington terminal (London); 30 tracks under cover, 15 miles of tracks, two-track line between Paddington station and Old Oak yards—Railway Gazette (London), 1939, April 21, page 639.

Coach Yards—Southern Pacific Railway; at San Francisco, and also serving new Union Station at Los Angeles—Railway Age, 1938, January 8, page 125; 1939, May 6 and September 9, pages 778 and 367.

Joint Operation of Facilities—Economic conditions and intensive use of railway facilities —AREA, Proceedings, 1939, page 124.

Lighting of Platforms—Conditions at London terminal stations—Railway Gazette (London), 1938, December 30, page 1131.

Location of Terminals—Economics of city and outlying location of terminal facilities—AREA, Proceedings, 1939, page 280.

Parcels Handling—Brussels station, Belgian National Railways; straight, circular and radial belt conveyors in sorting office—Railway Gazette (London), 1938, October 28, page 728.

Platform Shelters—Steel frame construction at Los Angeles Union Station—Railway Age, 1939, May 6, page 774.

Ramps—At San Francisco terminal of San Francisco and Oakland rapid-transit line; 10 percent grade, with non-slip surface—Architectural Record, 1939, July, page 31.

Stairways—Escalators and moving stairways—AREA, Proceedings, 1939, pages 250 and 735.

Stairways—Moving stairways in King's Cross station, London; traveling 125 to 180 ft. per minute—Railway Gazette (London), 1939, June 23, page 1006.

Stations—Abandoning small stations partly or entirely, and serving them by road, in order to improve main line operation—International Railway Congress, Bulletin, 1939, September, page 911.

Stations—Modernizing to meet changed conditions and requirements—American Railway Bridge and Building Association, 1938, Proceedings, page 61—Railway Age, 1939, January 7 and July 22, pages 27 and 132.

Stations—Prizes for neatness and maintenance; London & Northeastern Railway, Railway Gazette (London), 1938, September 9, page 440.

Stations—Rapid transit subway stations; comparison of various designs or layouts of tracks, platforms and columns; Paper by George Altvalter—Civil Engineering (American Society of Civil Engineers), 1939, August, page 477.

Stations—Subway stations at Chicago rapid transit line—Western Society of Engineers, Proceedings, 1938, December, page 289.

Track—Track reconstruction in two Chicago terminal stations—Railway Engineering and Maintenance, 1939, September, page 526—Concrete for Railways (Bulletin of Portland Cement Association), 1939, October, Vol. 3, No. 3.

Train Service—Formulas and mathematical theories as to trains and passengers; Paper by Dr. Ing. A. Patz, director of Budapest Railways—International Congress of Light Railways and Tramways; Proceedings of 1939 Convention at Zurich.

Waiting Rooms—Dreary aspects of facilities in English railway stations—Railway Gazette (London), 1939, July 14, page 42.

Water Supply—Insanitary conditions of water service to trains—Railway Age, 1938, September 17, page 403.

Freight Stations, Terminals and Yards

Car Retarders—Hydraulic systems; Loose and Frolich—Railway Gazette (London), 1939, August 18, pages 225 and 243.

Car Retarders—Layout at several yards—Union Switch & Signal Company, Bulletin 155, 1939, January.

Car Retarders—New York Central Railroad; electric operation at DeWitt yard, Syracuse, N. Y.—Railway Signaling, 1939, September, page 501.

Car Retarders—Pennsylvania Railroad; Enola yard, Harrisburg, Pa.—Railway Age, 1939, July 29, page 146.

Car Retarders—Skates or skids used at hump yards in India as auxiliary to hand brakes on cars; automatic removal before car stops. Used at Toudiarpet classification yard, Madras & Southern Mahratta Railway (India)—Railway Board, Government of India, annual report for 1937–1938, page 47.

Car Retarders—(See also Hump Yards).

Classification Yards—Elements of design—AREA Proceedings, 1939, page 282—Railway Age, 1939, March 18, page 487.

Classification Yards—Modernizing of yards and switching operations; including hump and flat yards, with car retarders. Paper by T. W. Royle, chief operating manager of London, Midland & Scottish Railway (England)—Railway Gazette (London), 1939, March 24, page 518.

Classification Yards—Operation on Indian Railways to reduce detentions of cars and to make up trains for long non-stop runs—Railway Board, Government of India; report for 1937–1938, page 47.

Clearances—Signs where clearance is too close for safety—AREA Proceedings, 1939, page 538.

Coal Handling—Aprons or chutes for transferring coal from side-door cars to motor trucks; car on low trestle to give gravity flow. Method advised by E. J. Garstang, of London, Midland & Scottish Railway—Railway Gazette (London), 1939, June 16, page 989.

Coal Tipple—Glen Alden Coal Company, Ashley, Pa.—Coal breaker and tipple served by Central Railroad of New Jersey—Coal Age, 1939, April and August, pages 32 and 68.

Coal Tipple—United Electric Coal Company; barge loading tipple on Illinois River 7-mile railroad from washer to tipple, where coal is fed from hopper to barge by a belt conveyor—Coal Age, 1939, May.

Coal Tipple—United States Fuel Company; breaker, washer and tipple at Hiawatha, Utah—Coal Age, 1939, June.

Coal Tipple—Youngstown Mines Corporation, West Virginia; mechanical plant for stocking and reclaiming at 150,000-ton stock pile—Coal Age, 1939, June, page 46.

Containers—Car-body containers as semi-trailers—Railway Gazette (London), 1939, June 2, page 805.

Containers—Cattle carrying by London & Northwestern Railway—Railway Gazette (London), 1938, September 23, page 525.

Containers—English railways; old (1831) and new styles—Railway Gazette (London), 1938, September 16, page 65 of "Supplement".

Containers—French and Netherlands railways; designs and methods of handling for rail and road transportation—Railway Gazette (London), 1939, March 10, pages 403, 413 and 417.

Containers—Interchange by trucks between terminals at St. Louis, Mo.; Columbia Terminals Company—Western Railway Club, Proceedings, 1939—Railway Age, 1939, May 20, page 878.

Containers—Insulated; for conveying chilled meat by rail from cold storage to steamers —Report of General Manager of Railways and Harbors, South Africa; 1938, pages 96 and 97.

Door-to-Door Service—Baltimore & Ohio Railroad; Truck-trailer system—Canadian Transportation, 1938, November, page 543.

Door-to-Door Service—Canadian National Railway; 6-ton truck at Montreal—Canadian Transportation, 1938, December, page 631.

Door-to-Door Service—English practice with motor and horse vehicles; operating costs; —Railway Gazette (London), 1938, November 18, and December 16, pages 868 and 1049.

Door-to-Door Service—Great Western Railway and London, Midland & Scottish Railway at Cardiff (Wales); 212 horse vehicles and 51 motor trucks with trailers; average 1075 railway cars inbound and 973 outbound—Railway Gazette (London), 1939, June 2, page 899.

Door-to-Door Service—Great Western Railway (England); producer-gas tractor—Railway Gazette (London), 1939, September 22, page 405.

Door-to-Door Service—London & Northeastern Railway, at Glasgow (Scotland); railway took over trucking contractor's equipment—Railway Gazette (London), 1938, December 16, page 1053.

Door-to-Door Service—London and Northeastern Railway; London service; 760 motor trucks and tractors, 595 horses—Railway Gazette (London), 1938, September 23, page 525; 1939, August 23, page 289.

Door-to-Door Service—Pennsylvania Railroad; car-body containers as semi-trailers—Railway Gazette (London), 1939, June 2, page 905.

Door-to-Door Service—Railway Express Agency; service at Denver, Colorado, for seven railways, including L.C.L. freight; 100 trucks, tractors and trailers—Railway Age, 1939, January 14, page 119.

Express Service—Railway Express Agency; review of centennial celebration and development of mechanical handling equipment at terminals—Railway Age, 1939, March 14, pages 363, 365, 369 and 371.

Fast-Freight Trains—Operating conditions—American Association of Railroad Superintendents, Proceedings, 1939—Railway Age, 1939, February 25, page 336.

Floodlighting—Yard installations; hump and flat yards—AREA Proceedings, 1939, page 73; also Bulletin 405, September-October, 1938.

Floodlighting—Toton yard of London, Midland & Scottish Railway; 100-ft. pylon carries four 1,000-watt lights; local lighting more effective in fogs, with lights on 25-ft. poles; at one end, where space does not permit poles, a 100-ft. tower carries four 1,000-watt lights at top and other lights at 25-ft.—Railway Gazette (London), 1939, August 18, page 243.

Freight House—Grand Trunk Western Railway; new freight house and equipment for car-ferry terminal at Milwaukee, Wis.—Railway Age, 1939, June 24, page 1064.

Freight House—Louisville & Nashville Railroad; Mechanical handling of freight—Railway Age, 1939, April 22, page 705.

Freight Stations—Improved methods of operation—Operating and Transportation Section, AAR Proceedings, 1939—Railway Age, 1939, May 20, page 873.

Freight Traffic—use of local trains, and abandonment of small stations (to be served by road) for improvement of main line traffic. Subject for report at International Railway Congress of 1941—Bulletin of International Railway Congress Association, 1939, September, page 919.

Grain Elevators—Handling in bulk for Great Lakes traffic; car unloaders and self-unloading steamers—Canadian Transportation, 1938, November, page 585.

Grain Elevators—Rock Island Lines; fire pump equipment of Chicago elevators—Railway Age, 1939, January 14, page 114.

Grain Traffic—Record of Canadian traffic in 1937, with distribution to various ports—Canadian Transportation, 1939, August, page 381.

Icing Stations—New methods of servicing refrigerator cars; Southern Pacific Railway—Railway Age, 1939, August 5, page 220.

Icing Stations—Platform with conveyor system; Belt Railroad of Chicago—Railway Engineering and Maintenance, 1939, April, page 244.

Hump Yards—Adjustable summit, operated by sliding wedges—Patent by W. A. Stainer and T. F. B. Simpson; London, Midland & Scottish Railway—Railway Gazette (London), 1938, November 25, page 921.

Hump Yards—Automatic operation in France, using motor-operated car retarders and rail contacts to record movements of cars and control car-retarders accordingly—Revue General des Chemins de Fer, 1939, June—Railway Gazette (London), 1939, August 23, page 271.

Hump Yards—Gravity switching methods, 1846 to 1939—Railway Gazette (London), 1939, August 18, page 225.

Hump Yards—Design and operation of classification yards—AREA Proceedings, 1939, page 282—Railway Age, 1939, March 18, page 487.

Hump Yards—Layout plans and pictures of several yards using car-retarders—Union Switch & Signal Company; Bulletin No. 155, 1939, January, page 68.

Hump Yards—Enola Yard, Harrisburg, Pa.; Pennsylvania Railroad, reconstruction, with new hump grades and car retarders—Railway Age, 1939, July 29, page 146.

Hump Yards—Toton Yard; London, Midland & Scottish Railway; hydraulic car-retarders, remote control of switches; hump track diverges to four tracks with car retarders and four groups of nine tracks each; 3,000 to 5,000 cars in 24 hours—The Engineer (London), 1939, June 9, page 709—Railway Gazette (London), 1939, May 26 and August 19, pages 877 and 228.

Hump Yards—Willesden Yard; London, Midland & Scottish Railway—Railway Gazette (London), 1939, March 24, page 521.

Industry Yards and Tracks—Grouted stone ballast and concrete pouring—Concrete of Railways (Bulletin of Portland Cement Association), 1939, October, Vol. 3, No. 3.

Joint Operation of Terminal Facilities—Methods and Economies—AREA Proceedings, 1939, page 125.

L.C.L. Freight—Economies and improvements in handling—Operating and Transportation Section, AAR Proceedings, 1939—Railway Age, 1939, May 20, page 874.

L.C.L. Freight—Fast trains for overnight service—Railway Age, 1939, March 18 and April 8; pages 457, 605 and 622.

L.C.L. Freight—Railway and trucking service—Railway Age, 1938, November 19, page 748—American Association of Railway Superintendents, Proceedings, 1938.

L.C.L. Freight—Railways should handle business now handled by freight-forwarding firms—Railway Age, 1938, November 19, page 745.

L.C.L. Freight—Terminal handling by Louisville & Nashville Railroad—Railway Age, 1939, April 22, page 704.

Loud Speakers at Yards—Equipment at Toton Yard of London, Midland & Scottish Railway—Railway Gazette (London), 1939, August 18, page 243.

Modernizing Yards—Remodeling of Northam Yard on Western Australian Government Railways—Railway Gazette (London), 1939, September 22, page 395.

Oil Siding—Protection from electric sparks—Signal Section, AAR Proceedings, 1939, Vol. 6, No. 2, page 259—AREA Proceedings, 1939, pages 73 and 772.

Passing Sidings—Layouts on Southern Pacific Railway—Railway Age, 1939, February 25, page 339.

Produce Terminals—Air-conditioning for storage and ripening of fruit and produce—AREA Proceedings, 1939, page 200—Railway Age, 1939, June 17, page 1031.

Produce Terminals—Denver, Colorado; cooperative project serves five railroads—Railway Age, 1939, August 5 and 19, pages 225 and 296.

Produce Terminals—Denver, Colorado; Union Pacific Railroad; food terminal market and storage, air-conditioning for storage and ripening—Railway Age, 1939—Kansas City Packer, 1939, September 23,—Traffic World, 1939.

Produce Terminals—Fruit handling from Italy to England by car-ferry in refrigerator cars using carbon dioxide gas—Railway Gazette (London), 1939, August 18, page 227.

Produce Terminals—Improvements needed; many plants now inadequate and antiquated—Engineering News-Record, 1938, September 22, page 349.

Produce Terminals—Handling fruit and vegetables on Southern Pacific Railway—Railway Age, 1939, August 5, page 219.

Refrigerator Cars—Brine dripping needs control—AREA Proceedings, 1939, page 583.

Refrigerator Cars—Carbon dioxide used in service between Italy and England—Railway Gazette (London), 1939, August 18, page 227.

Refrigerator Cars—Improvements on Canadian National Railways and Canadian Pacific Railway—Railway Gazette (London), 1939, September 29, page 427.

Scales—Specifications for two-section, knife-edge, track scales, and motor-truck scales—AREA Proceedings, 1939, pages 251, 267 and 736.

Scales—Track scale of 900,000 lb., plate fulcrum type, for Chicago, Burlington & Quincy Railroad at Lincoln, Nebraska—Railway Age, 1938, November 26, page 773.

Switching Engines—Automobile rail-car for yard and line service; Chicago, Attica & Southern Railroad—Railway Age, 1939, March 18, page 446.

Switching Engines—Electric, overhead-wire, 90-ton engines for hump yards—Railway Gazette (London), 1939, August 18, page 94 (Supplement).

Switching Engines—Oil-electric, 600 hp., for Central Railroad of New Jersey—Railway Age, 1938, December 31, page 955.

Switching Engines—Oil-electric, for Chicago, Burlington & Quincy Railroad, Chicago & North Western Railway, etc.—Railway Mechanical Engineer, 1939, July, page 286—Mechanical Division, AAR, Proceedings, 1939—Railway Age, 1939, July 15, page 108.

Switching Engines—Oil-electric of 1,000 hp. for Ford Motor Company—Railway Gazette (London), 1938, November 25, page 928.

Switching Engines—Oil-electric for Grand Trunk Western Railway—Canadian Transportation, 1938, September, page 433.

Switching Engines—Oil-electric, 105-ton, 700 hp.—Railway Age, 1938, September 10, page 387.

Switching Engines—Oil-electric; operating costs on Lehigh Valley Railroad—Railway Gazette (London), 1939, March 17, pages 41 and 43 (Supplement).

Switching Engines—Oil-electric engines in relation to smoke abatement—Railway Age, 1939, August 5, page 215.

Switching Engines—Oil-engine 44-ton machine for car repair yard of General American Transportation Company at East Chicago—Railway Age, 1939, September 23, page 436.

Switching Engines—Oil-engine hump locomotives at Toton yard of London, Midland & Scottish Railway—Railway Gazette (London), 1939, August 18, pages 245 and 248.

Switching Engines—Cost in terminal operation—Railway Age, 1939, April 1, page 558.

Switching Service—Use of loco-tractors on rail-and-road tractors at stations. Subject for 1941 convention of International Railway Congress—Bulletin of International Railway Congress Association, 1939, September, page 919.

Switching Tractor—Oil-engine tractor on balloon tires; for local yards where space is limited; 3-ton machine hauls 200-ton loads—Railway Gazette (London), 1939, July 28, page 147.

Terminal Avoidance—Russia builds by-pass lines at Moscow to enable through trains to avoid the city lines and terminals—The Engineer (London), 1939, September 15, page 479.

Transfer Platform—Gulf, Mobile & Northern Railway—Railway Engineering and Maintenance, 1939, January, page 33.

Transfer Trains—Interchange service connecting local freight stations and main line terminals at London—Railway Gazette (London), 1939, September 22, page 390.

Warehouses—Railway accommodation for storage of goods for merchants—Railway Gazette (London), 1939, August 23, page 272.

Yards—Clearance signs for close clearance—AREA Proceedings, 1939, page 538.

Yards—Outlying yards replacing congested city terminals—AREA Proceedings, 1939, page 280—Railway Age, 1939, March 18, page 487.

Yards—Main line traffic simplified by establishing large well-equipped classification yards to handle work now done at small stations. Subject for reports at convention of International Railway Congress in 1941—Bulletin of International Railway Congress Association, 1939, September, page 910.

Yard Tracks—Rail lubricators—Railway Engineering and Maintenance, 1939, March, page 166.

Yard Tracks—Switches; guards at switch rails—Railway Engineering and Maintenance, 1939, April, page 242.

Yard Tracks—Switches; reflector units in place of lamps—AREA Proceedings, 1939, page 566.

Yard Tracks—Switches; spring switches save time; Southern Railway—Railway Age, 1939, February 25, page 339.

Yard Tracks—Switch heaters; 154 in Clearing Yard of Chicago Belt Railway—Railway Engineering and Maintenance, 1939, March, page 145.

Yard Tracks—Switch heaters; hot-air blast devices (Germany) and electric heaters (Italy)—Railway Gazette (London), 1939, February 3, page 179.

Yard Tracks—Switch tenders; control of operators—Signal Section, AAR Proceedings, 1939, Vol. 36, No. 2, page 323.

Locomotive Terminals and Railroad Shops

Chicago, Burlington & Quincy Railroad—Maintenance facilities for oil-engine locomotives; paper by Mr. Urbach (with discussion as to other railways)—Mechanical Division, AAR Proceedings, 1939—Railway Age, 1939, July 15, page 110.

Danish State Railways—Facilities for servicing oil-engine rail-cars at Copenhagen; 10 parallel through tracks—Railway Gazette (London), 1939, March 17, page 45 (Supplement).

French National Railways—Concentrating rail-cars to facilitate inspection and repair; 743 rail-cars served at 61 terminals—Railway Gazette (London), 1939, August 4, page 117 (Supplement).

London & Northeastern Railway—Enginehouses and shops on the Darlington Division; 500 route miles, 170 passenger and freight stations—Railway Gazette (London), 1939, March 17, page 463.

London, Midland & Scottish Railway—Camden engine terminal at London—Railway Gazette (London), 1938, September 16, page 81 (Supplement).

Southern Railway—Berthing sheds for multiple-unit electric trains; car-washing machines; paper by W. J. England—Railway Gazette (London), 1939, April 28, page 44 (Supplement).

Wabash Railway—Storehouse supply record system for shops at Decatur, Ill.—Railway Age, 1939, February 4, page 234.

Western Australia Government Railways—Spray cleaning of locomotives—Railway Gazette (London), 1939, September 29, page 426.

Boilers—Control of blowing down of locomotive boilers—AREA Proceedings, 1939, page 243.

Cinder Pits—Description of various types—American Railway Bridge and Building Association, Proceedings, 1938, page 69.

Coal Storage—Cost and economy—Railway Age, 1939, July 29, page 188.

Coaling Stations—Economics of operating—AREA Proceedings, 1939, page 349.

Coaling Stations—Fire hazards and fire protection—Railway Engineering and Maintenance, 1939, July, page 417.

Coaling Stations—London, Midland & Scottish Railway; waste of coal; weighing and sprinkling coal—Railway Gazette (London), 1937, April; 1939, September 29, page 422.

Enginehouses—Bessemer & Lake Erie Railroad; reconstruction of enginehouse at Greenville, Pa.—Railway Mechanical Engineer, 1939, March, page 101.

Enginehouses—Pennsylvania Railroad; enginehouse at Harrisburg, Pa., with 125-ft. turntable—Railway Age, 1938, December 10, page 836.

Enginehouses—Window cleaning—Railway Engineering and Maintenance, 1939, May, page 313.

Enginehouses—Window and roof maintenance—American Railway Bridge and Building Association, Proceedings, 1939—Railway Engineering and Maintenance, 1939, November, pages 694 and 697.

Enginehouses—Operating methods—Railway Fuel and Traveling Engineers Association, Proceedings, 1938—Railway Mechanical Engineer, 1938, November, page 427.

Sand Drying Plant—Dry sand for sand boxes; Toronto Transportation Company—Canadian Transportation, 1938, May, page 237.

Scrap Handling—Cranes and other mechanical handling methods—Railway Age, 1939, June 17 and August 12, pages 1038 and 252—Purchases and Stores Division, AAR Proceedings, 1939.

Shops—Car repair shop; steel frame; Peoria & Pekin Union Railway—Railway Age, 1938, December 3, page 810.

Shops—Car-wheel shop practice—Mechanical Division, AAR Proceedings, 1939—Railway Age, 1939, July 1, page 17—Railway Mechanical Engineer, 1939, January, March and June, pages 29, 32, 110 and 242.

Shops—Coach repair shop at Danville for Chicago & Eastern Illinois Railroad; steel, brick and glass block; portable car-lifting jacks—Railway Mechanical Engineer, 1939, September, page 364.

Shops—Locomotive shops at Sacramento, California, for Western Pacific Railway—Railway Age, 1939, September 16, page 406.

Shops—Repair and inspection shops for oil-engine locomotives and trains; Belgian National Railways—Railway Gazette (London), 1939, September 29, page 153 (Supplement).

Shops—Roof and window maintenance—American Railway Bridge and Building Association, Proceedings, 1939—Railway Engineering and Maintenance, 1939, November, pages 694 and 697.

Storehouse—Layout and mechanical handling equipment; Union Pacific Railroad, North Platte, Nebraska—Railway Age, 1938, December 17, page 874; 1939, May 27, page 907.

Terminals—Economics of city and outlying locations—AREA Proceedings, 1939, page 280.

Terminals—Cost of handling locomotives—Railway Fuel and Traveling Engineers Association, Proceedings, 1938—Railway Age, 1938, October 8, page 515.

Terminals—Revision needed on account of changes in operating methods and locomotive design—Railway Age, 1939, January 7, page 27.

Terminals—Servicing locomotives—Western Railway Club, Proceedings, 1939—Railway Age, 1939, May 13, page 831.

Terminals—Servicing main-tracker fast-freight trains—Railway Age, 1939, September 9, page 379—American Association of Railroad Superintendents, Proceedings, 1939.

Terminals—Smoke abatement in relation to coal and oil fuel—Railway Age, 1939, August 5, page 214.

Turntables—Early designs; 1756 to 1842—Railway Gazette (London), 1938, November 11, page 820.

Turntables—Continuous girder type, 135 ft. long, for heavy engines, Northern Pacific Railway—Railway Age, 1938, November 12, page 698.

Turntables—Maintenance practice; Cleveland, Cincinnati, Chicago & St. Louis Railway —Railway Engineering and Maintenance, 1939, May, page 302.

Water Supply—Service pipe lines—American Railway Bridge and Building Association, Proceedings, 1938—Railway Age, 1938, November, page 663.

Water Supply—Facilities at Shopton, Iowa; Atchison, Topeka & Santa Fe Railway—Railway Engineering and Maintenance, 1939, May, page 305.

Water Treatment—Relation to locomotive economy—AREA Proceedings, 1939, page 733 —Railway Age, 1939, May and June, pages 867 and 957.

Rail-and-Water Terminals

Car Ferry—Bosphorus; Turkey to establish a crossing; $3,750,000—Railway Gazette (London), 1939, July 14, page 74.

Car Ferry—Danish State Railways; motor ships "Storeboelt", and proposed new route, Redby to Fehmarn—Railway Gazette (London), 1939, May 12 and July 21, pages 774, 775 and 106.

Car Ferry—Grand Trunk Western Railway and Pennsylvania Railroad—New facilities at Milwaukee for Milwaukee and Muskegon service—Railway Age, 1939, June 24, page 1064—Canadian Transportation, 1938, October, page 481.

Car Ferry—Seatrain Lines; Hoboken to Havana and New Orleans; car interchange with railways—Railway Age, 1939, August 26, page 319.

Coal Traffic—Demurrage rules in Great Lakes service—Railway Age, 1939, August 5, page 226.

Coal Traffic—Mechanical equipment for handling and shipping coal at 76 English railway-owned docks—Railway Gazette (London), 1939, July 14, page 44.

Docks—Reconstruction of concrete dock for ore unloader at Cleveland; Pennsylvania Railroad—Railway Age, 1939, January 28, page 185.

Ferries—New York and Staten Island; steamer 267 ft. long, 613 passengers. Also Annapolis and Claiborne, oil-engined vessel, 730 passengers—Marine Engineering, 1938, November.

Ferries—Quebec and Levis; triple-expansion, 170-ft. steamer "Louis Joliet"; passengers and automobiles—Canadian Transportation, 1938, September, page 470.

Ferries—Scotland and Ireland; London, Midland & Scottish Railway; twin-screw, oil-engined vessel "Princess Victoria"; 80 automobiles; stern loading to lower deck—Railway Gazette (London), 1939, July 14 and 28, pages 41, 66, 71 and 138.

Lake Shipping — Bulk-cargo, self-unloading steamers—Marine Engineering, 1938, December, page 571; 1939, January and February, pages 32 and 72.

Marine Passenger Station—Algiers, Morocco; new marine station and landing quay—Railway Gazette (London), 1938, September 23, page 518.

Marine Passenger Station—Calais; French National Railways; for Dover-Calais channel service; quayside platform 1,600 ft. long—Railway Gazette (London), 1939, July 31, pages 108 and 109—The Engineer (London), 1939, June 23, page 757.

Marine Passenger Station—Southhampton; Southern Railway; centennial of railway docks and terminals—Railway Gazette (London), 1938, October 14, page 643.

Piers—Baltimore & Ohio Railroad, Philadelphia, Pa.; pier and transit shed and cold storage facilities; glass blocks for buildings; timber construction for pier—Railway Age, 1939, February 18, page 307.

Piers—Chesapeake & Ohio Railway, Newport News, Va.; reconstruction of pier with car-dumper and coal loading machinery—Railway Age, 1939, April 29, page 741—Railway Engineering and Maintenance, 1939, June, page 352.

Piers—Norfolk & Western Railroad, Lambert's Point, Va.; and Huron, Ohio; coal pier and car-dumper—AREA Proceedings, 1939, page 289.

Piers—Design of coal, warehouse, car-float and other piers—AREA Proceedings, 1939, page 286—Railway Age, 1939, March 18, page 470.

Port Terminals—Facilities of Canadian Pacific Railway at Atlantic and Great Lakes ports—Canadian Transportation, 1939, April, page 199.

Port Terminals—Port charges and demurrage at Great Lakes ports—Railway Age, 1938, November 6, page 657.

Port Terminals—Charges for ship-rail interchange should be uniform, and not competitive —Houston Port Book, Houston (Texas) Port Commission, 1938, November; 1939, May.

Port Terminals—Tractors assist in loading and unloading steamers at New Orleans; reduce docking charges—Marine Engineering, 1939, April, page 181.

Report of Committee 27—Maintenance of Way Work Equipment

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To the American Railway Engineering Association:

Your committee respectfully reports on the following subjects:

1. Revision of Manual. No report under this assignment. Certain additions to the Manual are recommended under subject 2 below.

2. Standardization of parts and accessories for railway maintenance motor cars (Appendix A). Partially complete, and contains recommendations for additions to the Manual.

3. Lubrication of roadway machines. Progress in study—no report.

4. Self-contained direct-blow gasoline tampers (Appendix B). Progress report presented as information.

5. Concrete vibrators, collaborating with Committee 8—Masonry (Appendix C). Complete and presented as information.

6. Methods of keeping data on work equipment. Progress in study—no report.

7. Pneumatic-tired tractor equipment. Progress in study—no report.

8. Sand blasting equipment (Appendix D). Complete and presented as information.

9. Track welding equipment.
    (a) oxy-acetylene (Appendix E). Partial report, presented as information.
    (b) electric arc, collaborating with Committee 5—Track. Progress in study—no report.

10. Railway owned automotive equipment. Progress in study—no report.

11. Off-track ditchers. Progress in study—no report.

12. Rail loaders and unloaders (Appendix F). Complete and presented as information.

13. Safety devices for work equipment, collaborating with Committee 22—Economics of Railway Labor. Progress in study—no report.

The Committee on Maintenance of Way Work Equipment,

G. R. Westcott, *Chairman*.

Bulletin 414, December, 1939.

Appendix A

(2) Standardization of Parts and Accessories for Railway Maintenance Motor Cars

R. K. Johnson (chairman, subcommittee), G. J. Ermentrout, C. L. Fero, Jack Largent, R. A. Morrison, E. H. Ness, C. H. Ordas, R. R. Smith.

During this year, your committee has given consideration to the design of a gage for mounting motor car wheels. This is shown in Fig. 2708. The basis of this design is the same as that of the design of motor car axle shown in Fig. 2704 Rev., now in the Manual, and contemplates a gage for the wheels 13/16-in. less than the gage of the track, with no tolerance under and ⅛-in. over.

If a wheel gage greater or less than 55 11/16-in. is wanted, the length of the mounting gage must, of course, be changed accordingly.

Your committee also presents for consideration as recommended practice the following:

10. Differential axles.

Loose wheel axles shall be of the differential type and all wheels shall be insulated.

The considerations leading to this recommendation are:

(a) The cost of maintaining bronze-bushed loose wheels is abnormally high and the use of the differential-type axle is considered on the side of economy.

(b) The demand for more complete insulation of cars is strong and this can be accomplished only by insulating all wheels.

In connection with the insulation of four wheels, it should be noted that: (1) wood-center wheels are self insulating, and that (2) a wheel having a ball or roller bearing mounted in the hub can be insulated, and if used would serve the same end as the differential axle.

Recommendation

The committee recommends that:

(a) Fig. 2708 be adopted as recommended practice and printed in the Manual.

(b) That paragraph "10. Differential axles" shown above, be adopted as recommended practice and printed in the Manual.

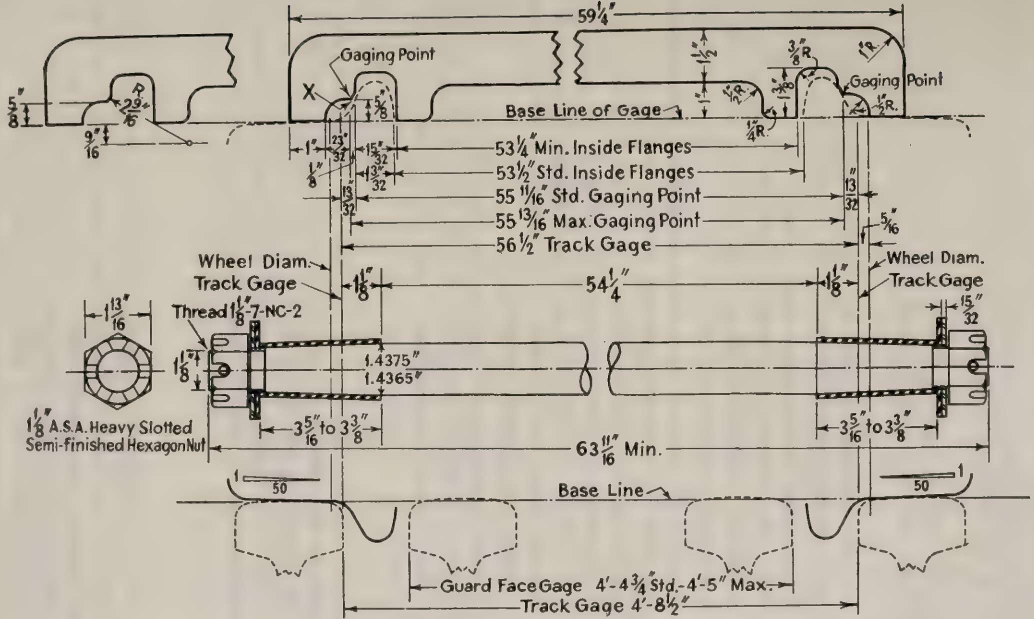
(c) That the assignment be continued.

Appendix B

(4) Self-Contained Direct-Blow Gasoline Tampers

C. R. Edwards (chairman, subcommittee), G. J. Ermentrout, Paul Hamilton, L. B. Holt, E. H. Mills, R. A. Morrison, C. H. Morse.

A full report on one type of self-contained direct-blow gasoline tamper was presented to the Association in 1938. While there are several types now in process of development, none has reached such a stage as to warrant further detailed report at this time.



NOTES: (a) Wheels shall gage same at four points on circumference.
(b) At maximum setting clearance at X shall be zero.
(c) At standard setting clearance at X shall be 0.105 inch.
(d) Gage shall be checked frequently against master gage.

FIG. 2708—Gage for Mounting Wheels on Maintenance Motor Cars

Appendix C

(5) Concrete Vibrators, Collaborating with Committee 8—Masonry

F. H. Rothe (chairman, subcommittee), G. E. Boyd, C. R. Edwards, W. G. Kemmerer, C. R. Knowles, R. A. Morrison, E. H. Ness.

The advantages and disadvantages of concrete placement by vibration have been covered by Committee 8—Masonry in its reports in Vol. 35, pages 967–972, and Vol. 38, pages 446–448.

This report covers the equipment available for vibrating concrete. Four sources of power are used for this purpose, namely, pneumatic, electric, hydraulic and mechanical.

Pneumatic vibrators operate in two ways—some embody oscillating pistons to set up vibration by hammer blows, others rotate eccentric weights on a shaft, thus developing a rotary or orbital vibration; numerous devices are used to impart these vibrations to the concrete.

Electric vibrators are of two general types—those developing a linear vibration by magnetic attraction and repulsion, and those rotating eccentric weights.

The hydraulic vibrator consists of an oil pressure pump which forces the oil through a flexible tube or hose operating and lubricating a turbine, which is designed to set up a rotary vibration. When the turbine rotor is in motion the frequency of vibration can be verified between reasonable limits by the speed of the oil pump, which is generally driven by a gasoline engine on a portable mounting.

The mechanical vibrator usually consists of a gasoline engine connected to a flexible shaft, generally with belts to produce the desired speed of rotation, the flexible shaft driving eccentric weights on a shaft inside of a spud, these spuds varying in size according to the type of work.

The linear or tapping type of vibration is generally used to improve surface appearance, while the rotary or orbital type is usually employed for the consolidation of the entire mass of concrete on the assumption that vibrating the concrete will break down the tendency of larger particles to lock before all interstices are filled.

To clarify the meaning of a vibration, we shall consider that one vibration is completed when the oscillating type of vibrator makes two strokes or completes one cycle, and when the rotary type makes one complete revolution.

Frequency

This phase of the work is subject to considerable discussion, and many factors, such as moisture, amplitude, characteristics of the aggregates, proportion of the mix, and the mass of concrete, must be co-ordinated with frequency. It is the opinion of some that vibrators are tools to facilitate the placement of concrete, while others contend that the vibrator should be used only to increase the density of the concrete. One specification in use by a large corporation reads—"An approved type of vibrator, having a frequency of not less than 3,500 impulses per minute, operated by being rigidly attached to the forms where the concrete is being deposited, or imbedded in the freshly deposited concrete to assist it into place, will produce maximum density, and prevent honeycombing." From this quotation it appears that some believe vibrators have a twofold purpose.

According to another source high speed vibration of concrete having a slump of 2½ in., or more, is likely to cause segregation of the materials. Therefore, numerous types of vibrators are required to comply with the demands imposed by these opinions.

There are concrete vibrators working today at speeds from 750 to 8,000 vibrations per minute, but most vibrators are operating within the limits of 3,500 to 6,000 vibrations per minute.

A report by M. C. Withey, professor of mechanics, University of Wisconsin, on "The Effects of Frequency of Vibration in Making Concrete Beams," reported in the Proceedings of the Highway Research Board for 1935, page 217, states that:

> If the field engineer could be assured that such dry consistencies (no slump or ½-in. slump) could be successfully placed with vibrators, their use would become general and better concrete would be obtained. The belief that the application of higher frequencies of vibration would aid greatly in reducing the time required to compact such dry mixes was the incentive for the experiments herein reported.

The following appears under Conclusions, paragraph three of Professor Withey's report:

> The estimated lengths of time required for satisfactory compaction of these beams by this 1¾-in. internal vibrator follow:

Time in seconds for unsatisfactory vibration for various frequencies

Slump	*4,000*	*5,000*	*6,000*	*8,000*
½-in.	90	45	25	not tested
None, 5% water	over 200	80	50	40

This definitely shows that high frequency vibration is desired both from the reduced time required to place concrete at the higher frequencies and to facilitate the placement of concrete of dry consistency. There is some objection to the high-frequency vibration on the part of both manufacturers and contractors, due to the excessive maintenance required on some vibrators to keep them working at the higher frequency.

Force of Vibration

The following figures are submitted by one manufacturer, the calculations being made by the manufacturers of the bearings used in his machine to determine the design of bearings to be used:

Speed R.P.M.	*Centrifugal Force—Lb.*
4,000	860
5,000	1300
6,000	1940
7,000	2620
8,000	3400

Knowing that centrifugal force varies directly with the square of the speed, these figures check approximately, and portray the relation between frequency and power required.

Professor Withey gives the following information in his report with respect to the electric-driven spud-type rotary vibrator used in preparing most of his test specimens.

Spud 1¾-in. in diameter, 20 in. long.

Total weight of spud 7.7 lb.

Weight of rotating rod and eccentric segments 3.35 lb.

Distance of center of gravity from longitudinal axis 0.2 in.

Amplitude of displacement on one side of neutral axis when suspended in the air and run at 5,000 to 7,000 r.p.m., approximately 0.15 in.

For an electric-driven external type of vibrator with variable settings, he found that at one-third of the maximum setting the amplitude was 0.030 in. and at maximum setting the amplitude was 0.055 in.

From the foregoing information it would appear that satisfactory results would be secured with a vibrator having an amplitude of 0.15 in. at a speed of 6,000 to 7,000 vibrations per minute to place no-slump five-percent water concrete, and that ½-in. slump concrete can be placed satisfactorily with the same vibrator at 5,000 vibrations per minute, but that the estimated time required is reduced 44.4 percent when the speed is increased to 6,000 vibrations per minute.

This information was obtained on relatively small masses of concrete in manufacturing beams for laboratory test. We may anticipate some deviation from these figures where larger masses of concrete are involved.

There are limits to the frequency and amplitude that may be used advantageously, as excessive frequency and amplitude combined will cause undesirable segregation of the aggregate. Therefore, if high frequency is used the amplitude must be small and if large amplitude is used the frequency must be low, both combinations having their place in certain types of work, depending on the moisture content and mass of the concrete.

Application

There are various methods of imparting the vibrations developed by the machines to the concrete.

The oscillating pneumatic type may be attached either to the forms or to single or multiple spades that penetrate the concrete.

The rotary pneumatic vibrators are used both for vibrating forms and for operating rotary spuds that are immersed in the concrete.

Electric vibrators of the linear-vibration type are generally used for vibrating forms only, while the rotary types are used for vibrating the forms, rotating spuds and vibrating various designs of plates, channels, etc. used as floats on the surface of the concrete.

The hydraulic and mechanical vibrators are usually used for operating spuds immersed in the concrete.

Conclusions

A. Linear or oscillating vibrators are less effective than orbital or rotating types for consolidating masses of concrete, but are satisfactory for vibrating forms.

B. Since the effect of vibrators applied on the forms penetrates the mass to a limited depth only, this method is most effective where the section of concrete is thin, or for producing a better surface under the form.

C. Rotating or orbital vibrators, as applied through a spud thrust into the mass of the concrete, are most effective in consolidating the mass.

D. Frequency rate and amplitude must be corelated.

E. The results obtained from a rotary vibrator of fixed characteristics of frequency and amplitude will vary with the characteristics of the mix as to moisture content and kind of aggregate.

F. Where a large volume of concrete is to be vibrated, it is desirable to use several vibrators instead of resorting to excessive frequency and amplitude of a single vibrator.

G. The choice of power to be used is largely dependent on local conditions, such as relative location of the work to the source of power, and the amount of concrete being placed.

The report is submitted as information.

Appendix D

(8) Sand Blasting Equipment

C. L. Fero (chairman, subcommittee), J. R. Derrick, E. C. Jackson, R. P. Winton.

Introduction

In the compilation of this report, the committee found that it must, of necessity, sharply limit the scope thereof, due to the fact that so few of the railroads do sand-blast cleaning in maintenance of way operations, and those to a comparatively limited extent. The resulting dearth of information precludes the inclusion of recommendations as to types and qualities of sand for particular jobs, cost comparisons for sand blasting vs. other methods of cleaning, and suggestions regarding procedure in specific applications.

Types of Sand Blasting Machines

Machines on the market today suitable for maintenance of way work can be divided into two groups, according to the method used in propelling the abrasive against the work.

Direct Pneumatic Pressure

The first group may be designated as direct pressure machines, the abrasive substance being blown from a container through a hose and nozzle by compressed air. Units of this type produce an intense abrasive stream of high velocity and are recommended for use where severe cleaning conditions are encountered and speed is desired.

Within this group comes a machine that, while operated by direct pressure, differs from others in the group in that, at the nozzle end of the hose, water is mixed with the sand by means of a special water-mixing device. It is claimed that this machine is advantageous in the cleaning of water-storage tanks having heavy deposits of lime and clay, because it is not necessary to permit such tanks to dry before blasting as would be the case if a dry sand blast were used.

Other advantages claimed are: Reduction of the dust hazard to a minimum; removal of dirt without injury to brick, masonry and joints; elimination of the viscous condition resulting from dry blasting of tar and asphaltum paint through water cooling; elimination of the oxidizing of cleaned metal surfaces by mixing a special chemical with the water; and the cleaning without discoloration of such surfaces as terra cotta and vitrified brick by the use of a chemical and fine abrasive. With a blasting machine, water control equipment, and steel skids for moving, the manufacturer shows weights varying from 1,350 lb. to 1,880 lb., depending on the sand capacity.

Suction

In the second group are the suction machines. In these a gun is used having a discharge nozzle behind which there is a chamber with connections for sand hose and air hose. When the air is turned on a partial vacuum is created within the chamber and the abrasive is drawn from its container, combining with the air and passing out through the nozzle. Fig. 1 shows typical construction of the suction-type gun. With this type of blasting machine, the work is somewhat slower, and the stream has not the intensity of that produced by direct pressure. These are intended for cases where cost is not paramount, where the work can be easily cleaned, or where the surface will not withstand the intensity of the direct-pressure blast.

Coming within this section category, but not to be characterized as machines, are the "midget" or "utility" blast guns. Maximum portability is afforded, due to the fact

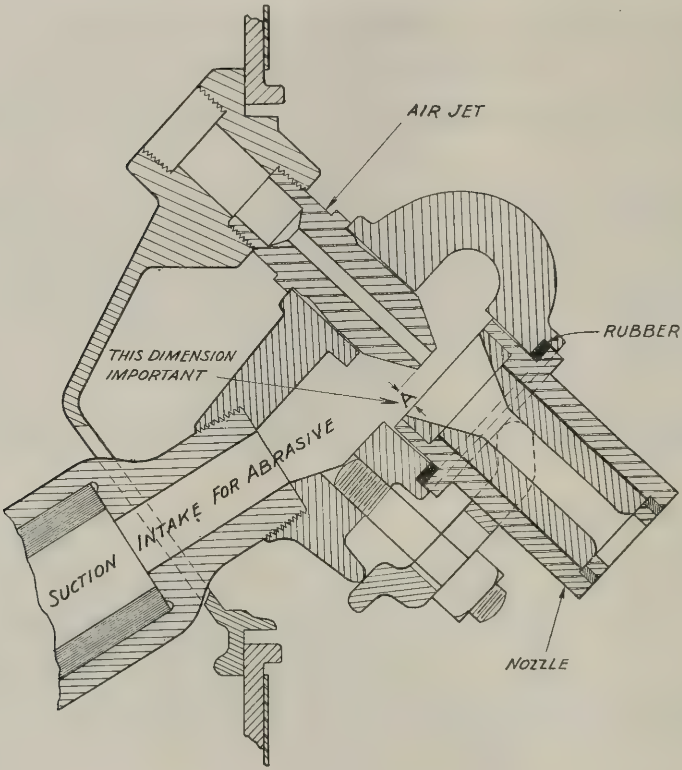


FIG. 1.—Typical Suction-Type Gun

that these units will draw abrasive from an open container, such as a pail or box, or from a pile of abrasive on the ground, without the necessity of transporting heavy tanks or cabinets to the job. Additional air tips of varying orifice sizes can be supplied to conform with available air pressure.

Other Methods

There in another group of machines that use other means than compressed air for the propulsion of the sand, grit or shot; the two outstanding methods being the blower and centrifugal force. In the former, the abrasive is fed into a blower and thus propelled against the work, while in the latter, the centrifugal force of a rapidly revolving wheel throws it at the parts to be cleaned. The stream of abrasive can be controlled, so that both work requiring intense blasting and work easily cleaned can be handled. Machines of these types are not generally adapted to maintenance of way work.

Advantages and Disadvantages

As a source of power for the propulsion of the abrasive, compressed air predominates. The chief disadvantage of air as the propelling agent is that the moving abrasive causes terrific wear on the blasting equipment.

Although the trend in recent years has been toward the elimination of compressed air in favor of some mechanical means, such as a blower or centrifugal force, the application of machines making use of these methods is limited and the cleaning done thereby is not always satisfactory. Work with this mechanical type equipment calls for a barrel or a cleaning chamber of some kind; and the machines are not, therefore, as easily adaptable to as many kinds of work as are machines using air pressure.

While it is recognized that compressed air is expensive, no substitute has as yet been developed that lends itself as readily to the manifold requirements of the various industries, or that produces work as uniformly satisfactory from the point of quality cleaning.

Moisture in compressed air is a troublesome and costly factor in blasting machine operation. It results in frozen or clogged air lines and in slow flow of the abrasive or clogged abrasive lines. There are devices on the market known as "separators" for the control of this condition. Where moisture is present in any quantity, the most satisfactory solution is to install an aftercooler on the compressor.

Air Pressure and Air Flow

The air pressure is subject to variation with the size of the compressor. The permissible pressure depends, also, on the impact of the abrasives that the surfaces to be cleaned will withstand. On work that will not warp under the impact of abrasives at high pressures, a generally recommended pressure would be from 80 to 90 lb. per sq. in. Pressures under this range will result in a proportionate reduction in the blasting speed; while higher pressures would not provide a sufficient increase in cleaning efficiency to compensate for the increased power consumption, equipment wear, maintenance cost, and the like.

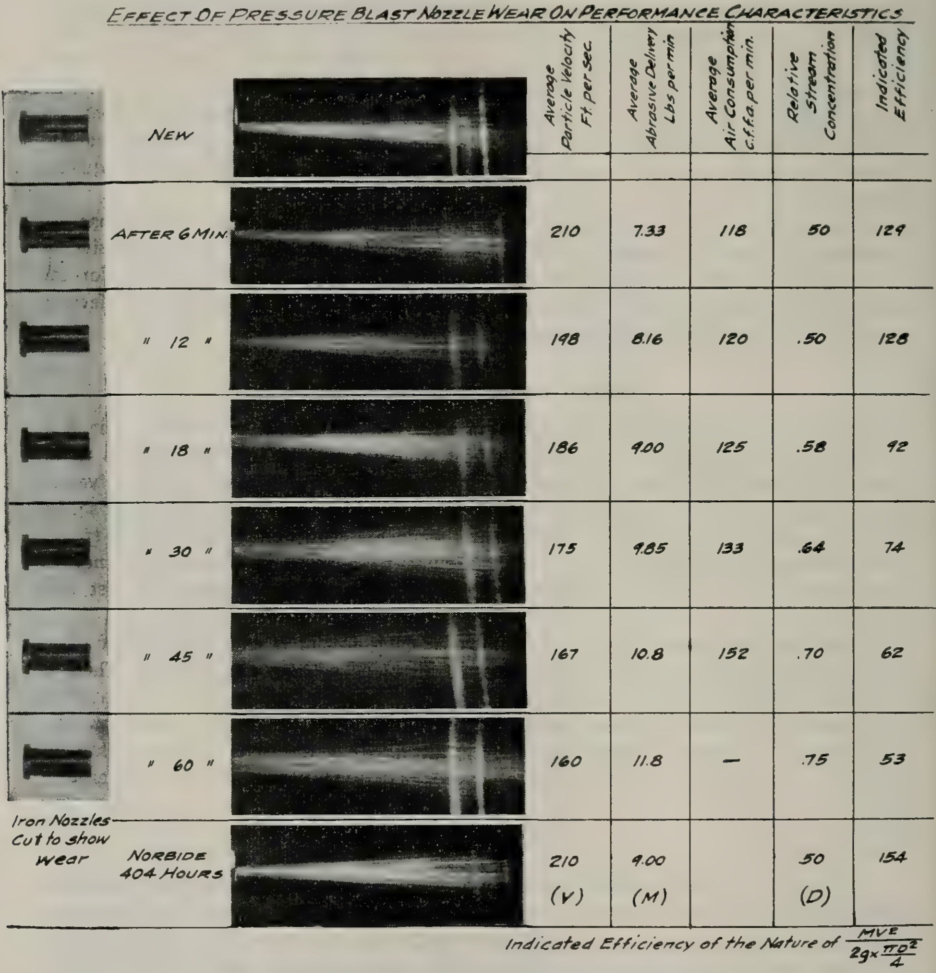
Air flow or air consumption is the number of cubic feet of free air flowing through a nozzle per minute and is based on the flow of air alone without any abrasive. There is a definite relation between the flow of air and the nozzle diameter, as is indicated in the general data tabulated under the heading of "Nozzles" of this report, which must be recognized if maximum efficiency is to be attained. When abrasive is flowing through a nozzle with the air, there is a drop of approximately 15 percent in the consumption of air.

Nozzles

In blast cleaning operations the size of the nozzle orifice determines the amount of propulsive energy that must be consumed to accomplish the desired end. Maximum efficiency can be had only when the discharge nozzle emits a concentrated abrasive stream with high abrading velocity and volume, and air consumption is retained at a commensurate minimum. Normal nozzle wear takes place in the form of a cone with its tip at the inlet end of the orfice.

The earlier nozzles were made of white iron, except within the past few years nozzles of this type were used almost exclusively on air blast cleaning equipment. The rapid wear begins to reduce operating efficiency almost from the first moment of their use. This situation prompted research that led to the development of boron carbide and cast tungsten liners for steel nozzles and the manufacture of nozzles of special manganese alloy steel. Fig. 2 shows comparative performance characteristics of iron nozzles and a nozzle lined with a non-metallic material.

A device designed further to increase blasting capacity and efficiency, especially in cases where large areas require uniform cleaning, is known as a rotary blast head. This head or gun carries from two to six nozzles and can be made to revolve either by an electric or an air motor. The rotation of the head produces a scrubbing effect on the area to be cleaned, leaving it free from the over-blasting that results when fixed



EFFECT OF PRESSURE BLAST NOZZLE WEAR ON PERFORMANCE CHARACTERISTICS

	Average Particle Velocity Ft. per sec.	Average Abrasive Delivery Lbs per min	Average Air Consumption c.f.f.a. per min.	Relative Stream Concentration	Indicated Efficiency
NEW					
AFTER 6 MIN.	210	7.33	118	50	129
" 12 "	198	8.16	120	.50	128
" 18 "	186	9.00	125	.58	92
" 30 "	175	9.85	133	.64	74
" 45 "	167	10.8	152	.70	62
" 60 "	160	11.8	—	.75	53
NORBIDE 404 HOURS	210 (V)	9.00 (M)		50 (D)	154

Iron Nozzles Cut to show wear

Indicated Efficiency of the Nature of $\frac{MV^2}{2g \times \frac{\pi D^2}{4}}$

FIG. 2.—Relative Efficiency of Iron and Non-Metallic Nozzles

nozzles direct more abrasive at the metal directly in the center of the stream, than at the outer edge thereof.

Another device for reducing the time for surface cleaning, while eliminating damage to the surface through the softening of the blasting action, is called a sand-blast gun. This gun is composed of an intake chamber housing and an outlet chamber housing with a baffle cup between the two. As the sand enters through the inlet nozzle, it meets the baffle cup and a whirling motion is set up which breaks down the sand particles, thereby increasing the number of cutting edges. The abrasive then passes between the baffle cup and the outlet chamber housing to the outlet nozzle. This outlet nozzle is flattened, the widths varying from two inches to more than four inches, and through this spreading or flattening of the flow of sand, injury to the surface being sanded is avoided and the cleansing time is reduced. Also, with this gun a less expensive sand can be used, due to the action of the baffle cup as indicated above.

The size of nozzle to be used would depend upon the speed of cleaning necessary, or it would be limited by the amount of compressed air available. The larger the nozzle the greater will be the speed of cleaning, so that it is generally desirable to use as large a nozzle as the air supply will permit. The tabulation below expresses in figures the approximate cleaning capacities and air requirements for the more prominent sizes of nozzles. It should be noted, however, that the data contained therein should be regarded as being of a general nature only, and it is suggested that specific applications be referred to responsible manufacturers.

Diameter of Nozzle Orifice inches	*Sq. Ft. Cleaned per min.*	**Air Flow at 80 lb. Pressure cu. ft. per min.*
3/16	2	47.5
1/4	4	85.0
5/16	5½	133.0
3/8	8	191.0
7/16	10	260.0
1/2	13½	340.0

---

* Free air—no abrasive being fed through nozzle.

Another influence upon the size of the nozzle to be used, is the size of the abrasive. According to one of the largest manufacturers of blasting equipment, his experience indicates that the best results are obtained if the diameter of the nozzle orifice is three times the size of the largest grain of abrasive to be used. A further consideration affecting the size of nozzle to be used is its relation to the size of the air jet, when employed in a suction-type machine.

A leading manufacturer states that for many years he had used a combination of nozzle and air-jet sizes wherein the diameter of the nozzle orifice was twice the diameter of the air jet orifice. However, as the result of a recent investigation he has found that it is possible to obtain equally good results as well as a reduced consumption of compressed air, through the use of a slightly smaller size of air jet. The present combinations of sizes recommended by this manufacturer, are as follows:

Diameters in Inches

Air Jets	*Nozzles*
5/32	3/8
7/32	1/2
9/32	5/8
5/16	3/4

Abrasives and Abrasive Flow

Sand

Maintenance of way work is, for the greater part, performed in the open where reclamation of the spent abrasive for re-use would be difficult. For this reason the use of sand will usually prove more economical. With sand as an abrasive, it is obvious, in view of the second paragraph below, why the guaranteed as well as the economic life of a discharge nozzle is approximately one-half that of a like unit used with a steel abrasive.

Steel

Steel abrasives are a cupola product, marketed in the form of steel "shot" and steel "grit", which are the "shot" crushed in ball mills. Steel "grit" is used for the preparation of surfaces where paint or a layer of metal is to be applied; "shot" is used for work that can be satisfactorily cleaned by shock; both being designed for reclamation and re-use.

In connection with the choice of abrasive, it should be noted that one cause of outlet wear on discharge nozzles, is the side thrust of the abrasive as the compressed air emerges into the atmosphere and, further, that the lighter the particles of abrasive, the greater will be the side thrust and attendant nozzle wear. Steel abrasives weigh about two and one-half times as much as sand.

A comparison of the abrasive flow per hour, as between sand and steel abrasive, through the common sizes of nozzles, and at 80 lb. pressure, is shown below:

Diameter of Nozzle Orifice Inches	**Abrasive Flow per Hour (in cubic feet)*	
	Sand	*Steel Abrasive*
3/16	6	5
1/4	10	8
5/16	13	12
3/8	19	16
7/16	25	20
1/2	33	28

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* Approximate.

As indicated, the figures above show the approximate consumption of abrasive through given size nozzles; but there is a certain range where efficiency is highest, which can best be worked out with the advice and co-operation of representatives of reputable manufacturers. Abrasive flow is sometimes impeded and efficiency reduced by the presence of excessive moisture in the air supplied for blasting operations. A leading manufacturer states that difficulties experienced due to excessive moisture are somewhat greater with steel abrasives than with sand. In explanation he adds that: "Sand will absorb a certain amount of moisture which is not true of steel abrasives, and the presence of moisture carried by the steel causes this material to 'cake' very rapidly, resulting in clogged abrasive lines and restricted flow of abrasive."

Sand-Blast Hose

Blast hose as supplied by the leading manufacturers is all essentially of the same construction. An inner tube of rubber reinforced by plies of double-weight duck, provides pressure-resisting strength and long life against the abrasives. The outside is covered with a compound of rubber to resist wear.

There is also available a hose with a compounded inner tube which is claimed to effect an almost complete elimination of static electricity sometimes present when a hand operated nozzle is used.

The size of blast hose used must bear a definite relation to the size of the nozzle and the length of hose line. If the hose line is too small in relation to the nozzle size, the abrading velocity through the hose will be too high, resulting in excessive wear in the hose. If hose size and nozzle are in proportion, it may be generally stated that with 100 to 150 ft. of hose, no great loss due to friction would be sustained. On the other hand, there would be a definite loss in efficiency due to friction from the use of runs of hose beyond these lengths.

Partial reduction of the loss of efficiency at the nozzle may be affected by increasing the diameter of the hose, thereby reducing the amount of friction; but such an increase must not destroy the proportionate relation between hose and nozzle sizes. The following tabulation sets forth the general proportionate relation between nozzle and hose sizes and hose lengths for good blasting efficiency, and is not intended to illustrate specific applications.

	Minimum Inside Diameter	
Diameter of Nozzle Orifice Inches	*30 to 40 ft. of hose Inches*	*100 to 150 ft. of hose Inches*
3/16	¾	1¼
¼	1	1½
5/16	1¼	1½
⅜	1½	1¾
7/16	1½	1¾
½	1¾	2

Where hose must be used vertically, the normal maximum lift may be set at about 50 ft.; and a greater vertical lift would result in considerable loss in efficiency because less sand would be carried at abrading velocity.

Conclusion

It is extremely difficult to cover the many angles of application in such a way that the information gathered can be applied generally to all uses. Such data must necessarily be of a general nature, and, depending upon the application involved, could easily prove misleading or be found inaccurate. For example, more square feet per minute could be cleaned on a water tank than would be possible on the open construction of a bridge. The nature and extent of foreign matter to be removed, accessibility, air pressures, length of hose, etc., all have a definite bearing on the speed of accomplishment.

It is suggested, therefore, that each application be taken up with a responsible manufacturer so that definite and accurate information can be obtained on that particular operation.

The committee recommends that this report be received as information and the subject be discontinued.

Appendix E

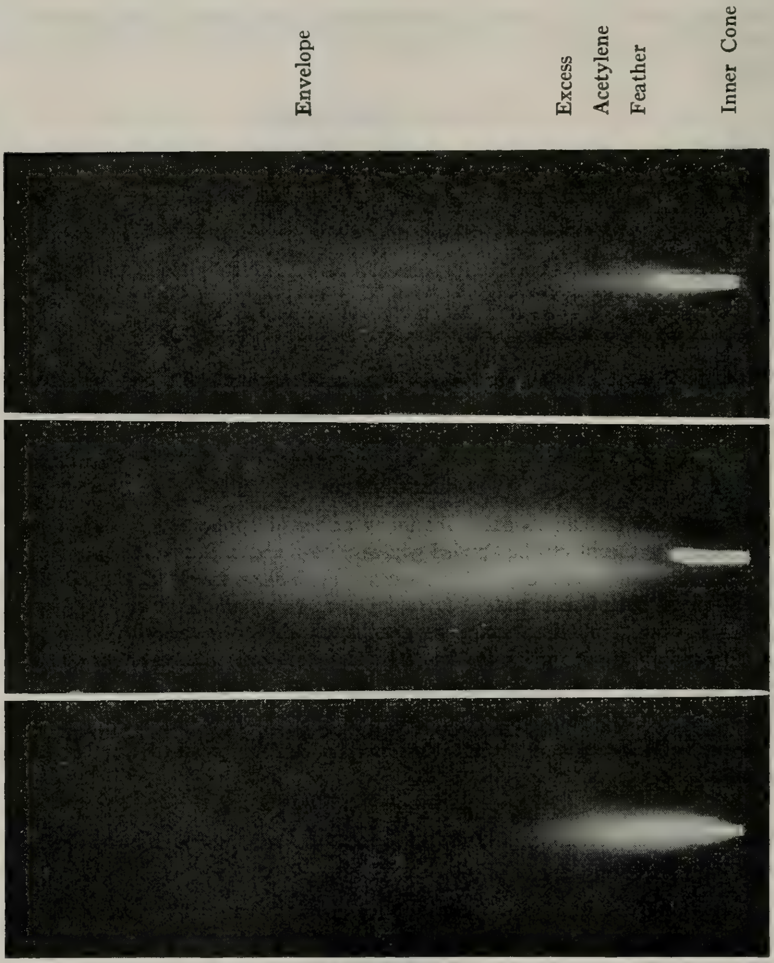
(9) Track Welding Equipment

J. G. Hartley (chairman, subcommittee), C. M. Angel, C. E. Herth, L. B. Holt, C. H. R. Howe, C. E. Morgan, E. H. Ness, E. L. Potarf, J. C. Ryan, R. P. Winton.

Introduction

The process of welding by means of the oxy-acetylene torch dates back only to 1900. About that time, Fouché of Paris, in conjunction with Picard, devised the first practical oxy-acetylene welding torch. After several years of experimenting they succeeded in producing a commercially successful apparatus about 1905.

In welding, sufficient heat must be generated adequately to heat the parent metal and the welding rod so that the metals will flow freely and fuse. For this purpose the oxy-acetylene flame has been the most successful gas combination, its temperature being the highest that can be produced by the burning of gases.



Top—Reducing Flame, Center—Neutral Flame, Bottom—Oxidizing Flame

The oxy-acetylene torch flame consists of two parts: An inner cone, which is incandescent and an outer envelope, or non-luminous flame, which is sometimes termed the secondary flame. The highest temperature of the flame is concentrated at the point of the inner cone. The character of the flame depends upon the proportion of oxygen and acetylene contained in the mixture and the thoroughness of the mixture as it issues from the welding tip. Varying proportions of the gases produce three characteristic types of flame:

(1) *Reducing (carburizing).*—The excess acetylene in this flame is fairly heavy and is indicated by the whitish "feather" extending past the inner cone, which is more clearly visible in the neutral flame. Even a slight trace of this feather at the end of the inner cone shows that the flame is still a trifle reducing.

(2) *Neutral.*—When the acetylene is reduced until the excess acetylene feather just disappears, the flame is neutral. This flame is that most commonly used and exists when approximately equal volumes of oxygen and acetylene are burned at the tip of a blowpipe.

The highest possible temperature is obtained with the neutral flame, the hottest part of which is just past the end of the inner cone.

(3) *Oxidizing.*—When the volume of acetylene in the neutral flame is decreased (or the amount of oxygen increased), even in slight amounts, the flame becomes oxidizing. The oxygen in this flame is in considerable excess, indicated by a purplish color and shortening of the inner cone.

Scope of Maintenance of Way Welding

The use of oxy-acetylene welding and cutting in railroad maintenance of way work began about 1918 in the building up of battered rail ends, and its use has been gradually amplified until today it is extensively used for field reclamation of rail ends, frogs, crossings, switch points, structural steel, and other work.

Originally a lack of new material and the necessity for handling increased traffic at minimum cost led some enterprising individuals to seek a new method of rehabilitating rail by rebuilding the ends on branch line main tracks having a preponderance of freight traffic. Freight traffic lines are generally laid with so-called "fit" rail removed from main line high-speed tracks, and this practice results in rails of different heights and head cross sections. To remedy this defect which was prolific of damage to heavily loaded freight equipment, and to secure maximum life of rail, the low end was built up to the approximate level and contour of the adjacent rail end by fusing metal from a welding rod to the heated rail, and reforming it by the use of a flatter and sledge.

As welding technique improved, there was a gradual extension of this practice to include rail in main track. Lack of continuous rigidity and the break in the surface of the rail at the joint brings about a condition generally known as rail batter which results in a flow of metal with consequent chipping and mashing of rail heads. Following successful experience in welding battered rail in main tracks, the practice has been gradually extended to include the wing rails and points of open hearth frogs, switch points, and on some railroads, wheel burns on heavy rail.

Welding Materials

Oxygen.—Oxygen is a colorless, tasteless, odorless, chemically active, gaseous element. It is not of itself combustible, but its property of supporting combustion renders it a preeminently useful gas for welding since it produces, with acetylene, a high temperature flame. It is usually obtained commercially by fractional distillation of liquid air. For best results in welding it should be as pure as practicable for a reduction in purity of one-half of one percent will decrease its efficiency as much as ten percent.

Oxygen cylinders must be made in conformance with ICC. specifications. They are usually about 51 in. high, with an inside diameter of 8.5 in., containing when full, approximately 220 cu. ft. of free oxygen, compressed to a pressure of 2,000 lb. per sq. in. at a temperature of 70 deg. F. The cylinders weigh about 150 lb. when full, and about 133 lb. when empty. All cylinders contain a safety plug which releases the gas when the internal pressure reaches 3,000 lb. per sq. in.

Acetylene.—Acetylene (C_2H_2) is a combination of about 92.3 percent carbon and 7.7 percent hydrogen, weighing 0.069 lb. per cu. ft. at 60 degrees Fahrenheit. Its characteristic odor is caused by traces of hydrogen sulphide and ammonia. It is the only one of the unsaturated hydro-carbons that absorbs heat during its production and liberates heat when it is decomposed. It is produced by the chemical action occurring when calcium carbide and water are brought into contact in a generator, and is usually produced by dropping carbide into water whereby the heat of the chemical action is absorbed in the water. One pound of a good commercial carbide should produce 4½ cu. ft. of acetylene gas.

If the small amounts of sulphur-phosphor compounds present are undesirable, the acetylene gas should be passed through a chemical reagent which will form non-gaseous compounds through combination of the reagent with the sulphur and phosphorous. To determine the relative purity of acetylene, a piece of white blotting paper may be moistened with a five-percent solution of silver nitrate and a stream of gas directed against it. Impure gas will immediately produce a dark brown, or black spot on the paper, whereas pure gas has no discoloring effect unless exposed to the atmosphere for an appreciable length of time.

Acetylene cylinders must be made in conformance with ICC. specifications. They are approximately 40.5 in. high, with an inside diameter of 12.1 in., weighing approximately 219 lb. when charged and 200 lb. when discharged. These cylinders have a capacity of of approximately 275 cu. ft. of acetylene compressed to a pressure of 250 lb. per sq. in. at 70 deg. F. The actual contents of charged cylinders are shown on attached tags. The amount of acetylene consumed from a cylinder should be determined by the relative weights of the cylinder when charged and when discharged, the difference in weight either being divided by 0.069 or multiplied by 14.5, but never should be computed from gage readings.

Certain liquids absorb acetylene, the most satisfactory being acetone, which has an absorbing power 24 times its own volume at atmospheric pressure and at ordinary temperature. Claude and Hess, by introducing acetone, as a retainer of acetylene into a cylinder containing a porous mixture of balsa wood and infusorial earth, were successful in storing acetylene under pressure with positive safety. The porous filler restrains the gas from free circulation and in case of explosion absorbs the heat so rapidly that the explosion is confined to a very small volume. The exothermic properties of the acetone counteract the endothermic properties of the acetylene, thus practically immunizing the acetylene-acetone mixture from dissociation in case of ignition or explosion.

Free acetylene, if compressed to approximately 25 lb. per sq. in., may explode under certain conditions, so its use at a pressure of more than 15 lb. per sq. in. is prohibited. The reduction from the high cylinder pressure to this safe working pressure must be effected by a regulator attached to the cylinder.

Welding Rods.—Welding rods vary as to size and composition. The rod to be used is dependent upon the character of the metal to be welded, and the purpose for which it is to be used. Sizes of rods range from $\frac{1}{16}$ in. to ⅜ in. in diameter, thickness or width and are usually 36 in. long. Some of the various kinds of rods are as follows:

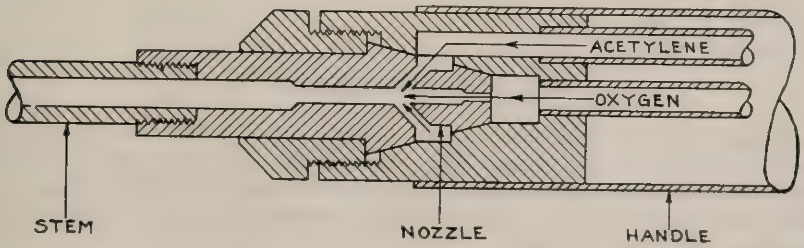
Low carbon steel
Mild steel
High carbon steel
Nickel steel
Vanadium steel
Chrome vanadium steel
Cast iron
Bronze
Manganese bronze
Brass
Cast silicon—aluminum
Drawn silicon—aluminum
Drawn aluminum
Deoxidized copper

Welding Equipment and Tools

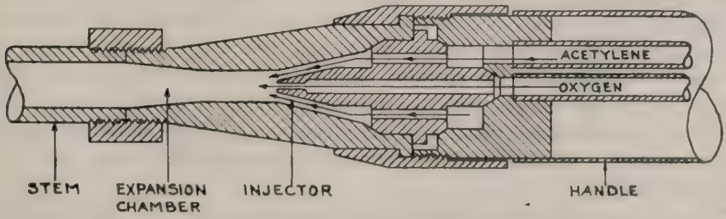
The equipment and tools required to satisfactorily perform welding by the oxy-acetylene method vary, but in general consist of the following:

1 Welding torch, complete with mixing head and welding tip.
1 Oxygen regulator, 450/3000 gage.
1 Acetylene regulator 30/400 gage.
Adaptors for acetylene cylinders to compensate, if necessary, for a variety of threads.
1 Acetylene cylinder key for each cylinder in use.
Four-way wrenches to accommodate nuts of all sizes used on the equipment.
1 Pair welders goggles, color shade 5 or 6, U. S. Bureau of Standards.
50 to 200 ft. of ¼ or ⅜-in. (green) oxygen hose with right-hand hose connections, and clamps of proper size.
50 to 200 ft. of ¼ or ⅜-in. (red) acetylene hose with left-hand hose connections, and clamps of proper size.
1 Friction spark lighter.
1 Pair welding gloves—gauntlet type.
Miscellaneous welding tools as required.

Welding torches.—Welding torches may be of the injector or pressure type. In the injector type the oxygen is under high pressure and the acetylene under low pressure. The injector type can be used with either low or medium pressure. The pressure type can be used only with medium pressure, the higher pressure of the oxygen drawing in the low pressure acetylene into the mixing chamber in approximately a constant ratio. In the pressure type, both gases are under considerable pressure which forces them into the gas mixing chambers. The torch consists of a handle into one end of which oxygen and acetylene are admitted separately through two needle valve-controlled inlets to a mixing chamber from which one outlet connects to a round welding tip at the other end.



Typical Medium-Pressure Blow Pipe



Typical Low-Pressure Injector Blow Pipe

Welding torches are manufactured in various lengths, sizes and weights suitable for the various classes of work to be done. However, with the injector type, suitable injectors must be provided for each size tip.

Welding tips.—Welding tips may be secured in a variety of sizes and styles suitable for the work to be done. Each size or style of tip gives a different size of flame, requiring varying amounts of gas. They may be swaged or separable, giving a long or a bulbous flame. Gooseneck or straight extensions are obtainable if required.

Ordinarily welding torches have provision for but a single flame, although torches having two or three tips are being used.

One railway has developed a two tip medium pressure torch (shown in Fig. A). This consists of two No. 10 tips coupled together and connected to a common gas distribution chamber which in turn is connected to the gas mixing head. The tips are so positioned as to direct the flames against the rail surface in lines normal to the top surface curvature of the rail head. The spacing between the tips is such as to utilize freely the atmospheric oxygen without interference with each other. As the flames cover twice the surface covered by a single flame it is necessary to use a flat ribbon welding rod 1/16 in. thick and 3/4 in. wide.

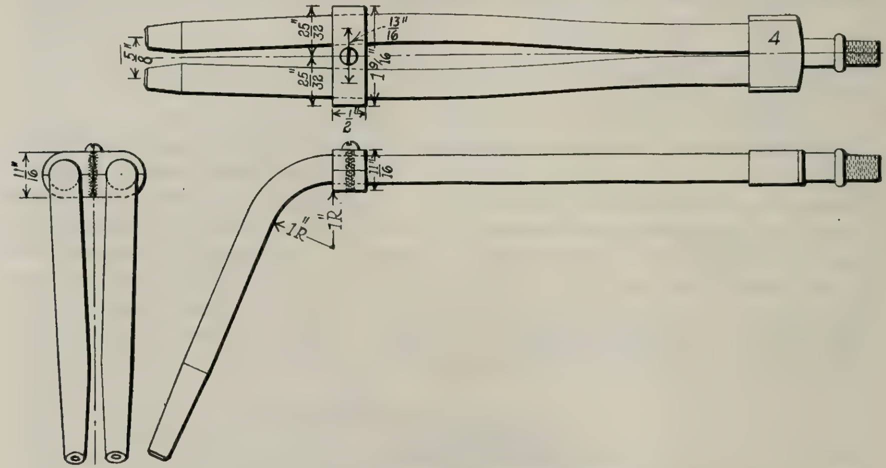


FIG. A.—Two-Flame Welding Tip

The same railway has further expanded the idea of using multiple-flame tips by developing a three-tip medium pressure torch which is shown in Fig. B. In this device the tips are mounted in a carriage supported on the rail head by rollers which permit a longitudinal movement along the rail. The tips are disposed and positioned in a manner similar to those of the two-tip torch, and their height above the surface of the rail is readily controlled by the operator, through a simple mechanical adjustment.

The consumption of gas with the three-tip torches is of such volume that it is necessary to provide three cylinders of acetylene, connected by approved manifolds, in order to maintain a suitable working pressure, and to prevent drawing over of acetone with the acetylene.

The purpose of the two and three-tip torches is to reduce the time required to preheat the rail, melt the rod and fuse the two together.

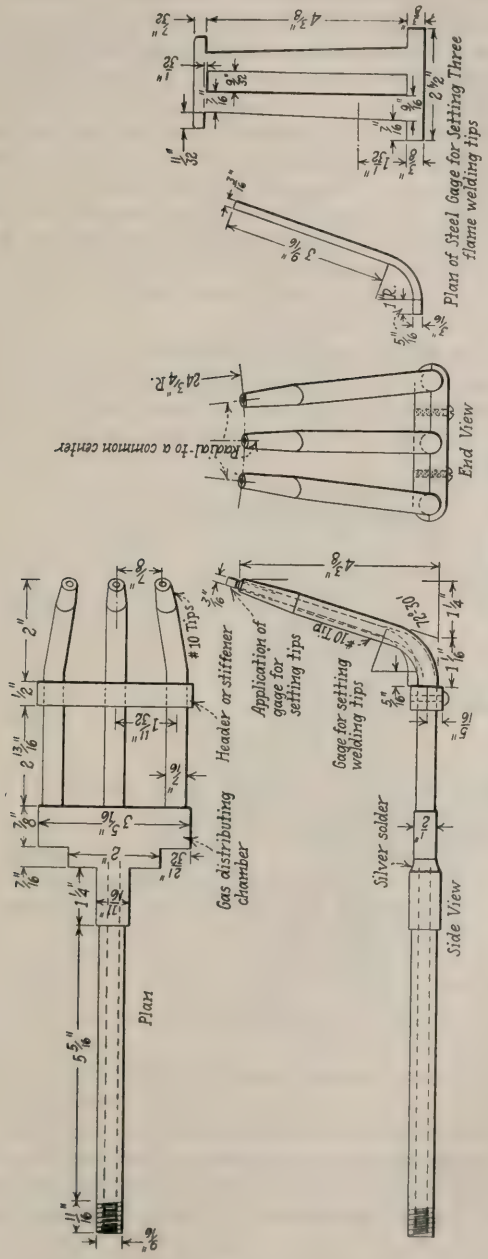
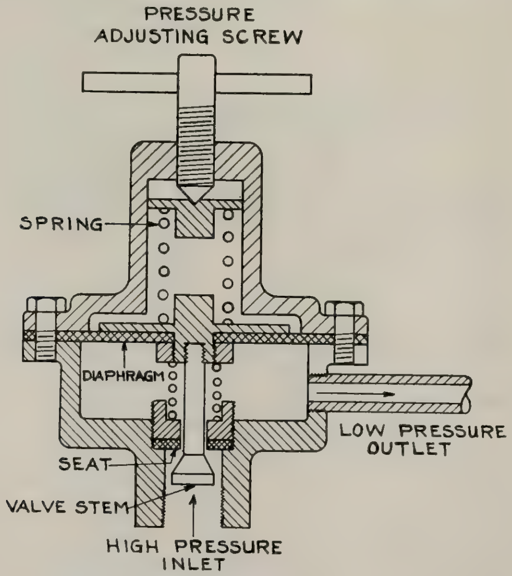


FIG. B.—Three-Flame Welding Tip

Regulators.—The oxygen and acetylene gases, as delivered for use in their respective cylinders, are under high pressure and since, for efficient welding and safety, the oxygen and acetylene must pass to the welding tip at a proper and constant pressure, regulators are necessary. The ideal regulator should maintain constant working pressure as the cylinder pressure decreases.

Various types of regulators are commercially available and are fairly similar in design and construction, consisting principally of the body proper, regulator valve, diaphragm, pressure-adjusting spring, compensating spring, safety relief valve, and gages. The pressure-adjusting spring is set by means of an adjusting screw for the pressure desired at the tip, which spring, actuating the diaphragm, controls the pressure. In some types of single-stage regulators the working pressure decreases as the cylinder pressure decreases, while in other types the working pressure increases as the cylinder pressure decreases nearly to the working pressure.

Oxygen regulators are usually equipped with two dial gages, one indicating the pressure and amount of gas in the cylinder; the other indicating the working pressure. The two basic types are the nozzle type and the stem type, the former having a movable valve seat bearing on a fixed nozzle and the latter having a movable valve which fits into a receptacle in the seat.



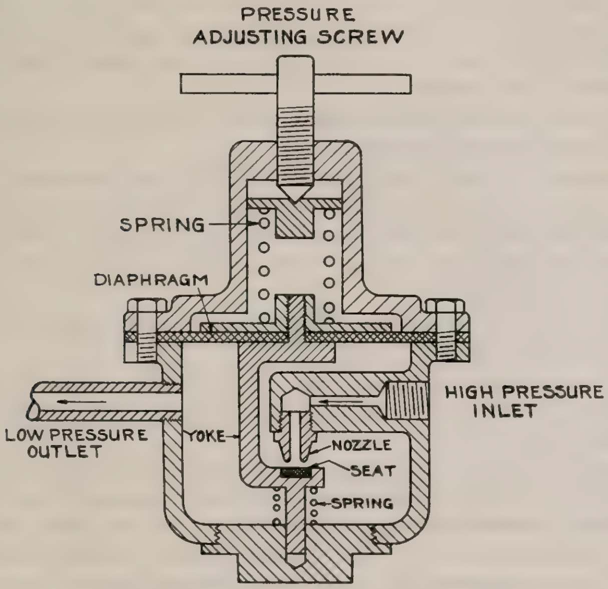
Typical Inverse (Stem) Type Regulator

Two-stage regulators are also available. They have two reductions in pressure between the cylinder and the tip, the first stage being fixed, and the second adjustable. The advantage of the two-stage regulators is that they maintain more uniform working pressure and minimize trouble from moisture freezing on the valve seats during cold weather.

Acetylene regulators also are usually equipped with two gages; one indicating the pressure in the cylinder but not the quantity of gas, since the quantity is not proportional to the pressure, and the other showing the working pressure.

Manifolds.—Where it is necessary or desirable to use acetylene from two or more cylinders, a manifold equipped with flashback arrestors is attached to the cylinders.

Hose.—Hose is available in various sizes and lengths. It should be of sufficient strength to resist the pressure of the gases and withstand the constant bending and twisting incidental to the work. It is also desirable to have it furnished in green for oxygen and red for acetylene, to avoid error in connecting and avoid any danger from interchanging.



Typical Direct (Nozzle) Type Regulator

Procedure For Operating Oxy-Acetylene Outfit

Setting Up Outfit, Preliminary to Welding

Oxygen.—

1. Stand to one side of the opening and partially open (or crack) the valve on the oxygen cylinder, so as to blow out any foreign particles.
2. See that the pressure adjusting screw on the oxygen regulator is completely released.
3. Connect the oxygen regulator to the oxygen cylinder and tighten the nut securely, with the proper wrench (this is a right-hand thread).
4. Connect the oxygen hose (green) tightly to the oxygen regulator fitting for that purpose, using the proper wrench (a right-hand thread).
5. Turn on the cylinder valve very slowly, allowing only enough oxygen to be discharged into the regulator so that the gage needle will show a very slow movement upward. This will insure against injury to the diaphragm, seat, or gage.
6. Turn on the oxygen regulator pressure-adjusting screw and blow out the hose, being sure that it is completely cleaned out.

7. Connect the oxygen hose to the oxygen connection on the torch, securing it tightly, with the proper wrench (a right-hand thread).
8. Open the oxygen-torch needle valve and again screw in the oxygen regulator adjusting screw, in order to blow out or clear the torch with the welding tip off. After determining that there are no obstructions, close the oxygen torch needle valve.

Acetylene.—

9. Acetylene cylinders must be kept in an upright position for at least 12 hours before using, in order to prevent release of free acetone, which is injurious to regulators and torches.
10. First open the acetylene cylinder valve (crack it) in order to remove any accumulated foreign matter from the valve.
11. Be sure that the pressure-adjusting screw is released and then inspect the acetylene regulator to see that the cylinder connection is free from grit or dirt; then connect it securely to the acetylene cylinder with the proper wrench.
12. Connect the acetylene hose (red) to the regulator outlet with the proper wrench (a left-hand thread).
13. Open the valve on the acetylene cylinder slowly one and one-half turns to prevent injury to diaphragm, seat or gage.
14. Turn on the pressure-adjusting screw of the acetylene regulator and blow out the hose, making sure that no obstructions exist and then unscrew the pressure-adjusting screw.
15. Attach the acetylene hose to the acetylene connection on the torch, with the proper wrench (a left-hand thread), blow out the torch with the tip off, following the same procedure as in Item 8 and replace welding tip.
16. With the acetylene valve on the torch closed, open the oxygen valve on the torch to set the oxygen regulator to the desired pressure; then close the oxygen torch valve.
17. Open the acetylene valve on the torch and set the acetylene regulator to the desired pressure.
18. Be sure that goggles are over the eyes.
19. Light the torch with a standard friction lighter in accordance with the instructions of the manufacturer.

Taking Down Outfit, Following Welding

1. Extinguish torch flame by turning off first the acetylene needle valve on the torch to eliminate the possibility of continued burning in the mixing chamber; then turn off the oxygen needle valve on the torch.
2. Shut off the oxygen and acetylene cylinder valves in turn.
3. Reopen the acetylene and oxygen needle valves on the torch to release pressure on each hose and again close the valves.
4. Unscrew or release the oxygen and acetylene pressure-adjusting screws.
5. Unscrew the regulator connection on the oxygen cylinder and replace the cylinder cap.
6. Unscrew the acetylene regulator connection, remove the regulator and replace the cylinder cap.
7. Always use proper wrenches on torches, regulators and cylinders.

Precautions to be Observed

All work should be done in accordance with "Safe Practices for Installation and Operation of Oxy-Acetylene Welding and Cutting Equipment", published by the International Acetylene Association, and the regulations of the National Board of Fire Underwriters for the installation and operation of gas systems for welding and cutting.

The report is presented as information with the recommendation that the subject be continued.

Appendix F

(12) Rail Loaders and Unloaders

T. M. Pittman (chairman, subcommittee), J. R. Derrick, E. C. Jackson, R. K. Johnson, W. G. Kemmerer, Jack Largent, R. M. Leeds, E. H. Mills, A. W. White.

Machines that can be used only for loading or unloading rail are not economical, as they are idle too much of the time. They are still being used by railroads that have them, but when new machines are purchased, consideration should be given to those that can be used for all classes of rail handling, as well as for other classes of work. A comprehensive report on rail loaders and unloaders, therefore, should include a discussion of the more versatile machines. A very important use of cranes for handling rail is offered in the relaying of rail in tracks. The handling of rails from piles can be done with almost any crane, but the efficient handling of rail into the track requires a machine with rather definite characteristics. These characteristics will not interfere with any other jobs of rail handling and will permit a wide range of use of the machines for other classes of work.

A survey of equipment used for handling rails on several representative railroads indicates the practice of using whatever type of crane is available at the time the work is being done, and the use of special machines for handling rail is far from universal. Frequent use is made of shovel-type ditchers, steam locomotive cranes and pile drivers, as well as home-made devices assembled from old machines of various types. Most of the roads use small power cranes, which are especially adapted to handling rail, but can also be used for many other purposes.

The earlier machines were of the hand crank or windlass type. These were superseded by machines that receive their hoisting power from compressed air, usually taken from the locomotive of the work train. The boom has to be swung by hand and several men are required to operate it. These are generally mounted on a flat car and are not self propelling. They cannot be used to lay rail, but only to load and unload it. Some types of air loaders have proved very efficient within the range of their limitations. One has an air reservoir located at the center of a flat car, to which cylinders are connected at both ends, giving, in effect, two machines powered from a single reservoir. There is a boom at each end of the car and the rail is handled by cables connected with the pistons of the cylinders and passing over wheels at the end of the booms. The range of lift is controlled by means of a system of pulleys. A locomotive with a large compressed air capacity is required to provide adequate power for both cranes. The operation is simple and the machine can be operated by section labor where not in conflict with the working agreements. Larger machines use steam power obtained from boilers mounted on the same car as the engine. In some cases these cranes are used also for driving piles. The development of the internal combustion engine led to the adoption of gasoline and Diesel motors for power plants and the flexibility of machines powered with these motors resulted in the development of cranes with a wide range of capacity and versatility.

The design of a crane for handling rail has not been standardized and probably never will be, except within rather broad limits, as the details may be worked out in many ways without affecting the efficiency of the machine. The following characteristics are desirable:

> The boom should be long enough to handle the longest rail used. It is probable that the present standard length of 39 ft. will ultimately be increased to 45 ft. No doubt, some use will be made of 78-ft. rail, but the trend of opinion would indicate that 78 ft. will not be adopted for the standard length of rail in the near future. A boom 28 ft. to 30 ft. long will handle a rail 45 ft. long under ordinary conditions, but a boom 45 ft. to 50 ft. long will be necessary for a 78-ft. rail. Where rail is handled from a high-side gondola car it may be necessary to increase the boom length in order to get over the side of the car. On one machine, the heel of the boom can be raised vertically several feet, while on another a curved boom is used to avoid lengthening the boom.
>
> The lifting capacity should be great enough to handle the heaviest rail, frog or crossing used, with a liberal reserve to meet future requirements.
>
> The machine should be as light as possible, consistent with sturdy construction.
>
> The machine should have a full-circle swing.
>
> The machine should be self propelling.
>
> The tail swing should be as short as possible, counter-weights being used to reduce the overhang. If possible, the adjoining track should not be fouled when the machine is turned at right angles to it. Otherwise, it will be necessary to have flag protection on the adjoining track.
>
> The line speed should be as fast as possible, consistent with the picking up of heavy loads.
>
> The controls should act quickly and the releases free easily.
>
> The motor should have a quick pick-up.
>
> The machine should be powered with a gasoline or Diesel motor.
>
> If track-mounted and to be used for switching cars, the machine should be equipped with couplers and air brakes.
>
> The side-swing controls should be dependable and provided with quick acting and positive locks strong enough to hold the boom in any position.

A popular type of machine, now used by a number of railroads, has a lifting capacity of from two to eight tons, depending upon the size of machine, and weighs up to twenty tons. These machines can handle a 39-ft. rail of the heaviest section in general use without difficulty, and the larger ones can handle a 45-ft. rail. For handling a 78-ft. rail, however, a longer boom and one of the heavier machines will be required.

Developments in off-track machines and their greater use on railroads presage an increasingly wide use of them for all types of rail handling. Their mobility gives them a distinct advantage for handling rail from piles and they have several advantages over the on-track machines for laying rail. In loading or unloading rail from flat or open-end gondola cars, the off-track machine can be run from one car to another and any number of cars can be worked without having to run to a side track to switch the machine between the two cars to be worked, as is necessary with the on-track machines. When making closures to pass trains, the off-track machine can be run to the side of the track to clear, while the on-track machine must run to a side track, which may be several miles distant. Then, too, there is the matter of paying a train crew with the on-track machine that is not required with an off-track machine.

Some of the advantages and disadvantages of the two types of machines are given below:

On Track Machines

Advantages

Does not require steering, which leaves the operator free to devote his entire attention to the controls.

Can run faster, which will enable it to get to and from work quicker.

Disadvantages

Has to run to a siding to clear trains.

It is necessary to switch it between the two cars being worked.

Requires a train crew.

Cannot be used for other classes of work except where tracks are available.

Longer and more frequent delays on account of traffic.

Off Track Machines

Advantages

Can clear the track without going to siding.

Does not require a train crew.

Will run from car to car, making it unnecessary to run to siding and switch after working two cars.

Fewer and shorter delays from traffic.

Easier to load and unload from cars, when transporting to another location.

Has wider range of usefulness in other classes of work.

Disadvantages

Slower traveling speed.

On some types, the running gear fouls the rail.

Necessity for steering might take more of operator's time and delay the work when laying rail. Since steering can be done while crane is moving forward, this should not amount to much with an experienced operator.

Since few railroads have enough work to keep a machine busy handling rail, it is important that consideration be given to using the machine on other classes of work when not needed for handling rail. This consideration might require the modification of some of the desirable features of an exclusive rail handling machine, but the factor of economy will generally outweigh any objection to the modification. Under any circumstances, machines should be bought that have large enough production to bring the price within reason and for which repair parts are available at a fair price.

Conclusions

Machines that can be used only for loading and unloading rail are not economical.

When purchasing new machines, consideration should be given to the adaptability of the machine to laying rail and other classes of work.

The greater development and use of off-track machines will prove economical.

This report is presented as information.

Report of Committee 12—Rules and Organization

W. T. DORRANCE, *Chairman,*	W. O. CUDWORTH	J. C. IRWIN, *Vice-Chairman,*
J. B. AKERS	G. H. HARRIS	B. R. KULP
W. C. BARRETT	G. W. HARRIS	C. H. MOTTIER
D. P. BEACH	E. M. HASTINGS	R. C. WHITE
RICHARD BROOKE	A. A. JACKSON	F. B. WIEGAND
		Committee.

To the American Railway Engineering Association:

Your committee respectfully reports as follows on the subject assigned to it:

The committee has made progress in its assignment, and as is customary, is handling the work through various subcommittees.

It has held three meetings during the year with a very gratifying number of the members present at each meeting. At these meetings the reports of the different subcommittees were given detailed consideration and were fully discussed.

The subject requires a very thorough review of the work done in the past and already approved by the Association, and your committee has found in its work during the year that it must give still further study to the subject and needs the collaboration of various other standing committees with reference to their particular fields of work. Your committee can therefore only report progress at this time.

THE COMMITTEE ON RULES AND ORGANIZATION,
W. T. DORRANCE, *Chairman.*

Bulletin 414, December, 1939.

Report of Committee 22—Economics of Railway Labor

G. M. O'Rourke, *Chairman,*
Lem Adams
C. W. Baldridge
E. J. Bayer
F. J. Bishop
W. H. Brameld
H. A. Cassil
J. I. Catherman
Armstrong Chinn
C. M. Chumley
E. A. Craft
R. R. Cummins
F. L. Guy
G. H. Harris
J. G. Hartley
A. C. Harvey
Elmer T. Howson
H. E. Kirby
D. A. Kuebler
H. T. Livingston
G. M. Magee
J. B. Martin
J. S. McBride
E. H. McIlheran
L. L. Adams, *Vice-Chairman,*
F. R. Paisley
J. A. Parant
C. H. Paris
A. E. Perlman
W. G. Powrie
F. S. Schwinn
R. L. Sims
H. M. Stout
W. H. Vance
C. R. Wright
Committee.

To the American Railway Engineering Association:

Your committee respectfully reports on the following subjects:

1. Revision of Manual. None to be made.

2. Analysis of operations of railways that have made marked progress in the reduction of labor required in maintenance of way work (Appendix A). Complete and presented as information.

3. The relative economy of combined vs. separate bridge and building gangs. Progress in study—no report.

4. The effect of modern equipment and machines on bridge gang organization and efficiency (Appendix B). Complete and presented as information.

5. Review and revise factors previously established for equating track values for labor distribution. Progress in study—no report.

6. Labor economies possible through the use of highway motor vehicles for maintenance forces. Progress in study—no report.

7. Added labor economies resulting from use of off-track maintenance equipment. Progress in study—no report.

8. Labor economies which may be effected through revision of operating and maintenance of way and structures rules (Appendix C). Complete and presented as information.

9. Economies in labor resulting from the reduction in track patrol made possible through improvements in track conditions (Appendix D). Complete and presented as information.

The Committee on Economics of Railway Labor,
G. M. O'Rourke, *Chairman.*

Appendix A

(2) Analysis of Operations of Railways That Have Made Marked Progress in the Reduction of Labor in Maintenance of Way Work

H. A. Cassil (chairman, subcommittee), Lem Adams, E. J. Bayer, E. A. Craft, Elmer T. Howson, G. M. Magee, J. B. Martin, J. S. McBride,, F. R. Paisley, J. A. Parant.

The committee concentrated its attention under this assignment this year on a study of the track supervisor system in effect on the Chicago, Burlington & Quincy and the Chicago, Rock Island & Pacific railways, a system which interposes track supervisors

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between the section foremen and their district roadmasters, giving the supervisors the primary responsibilities of direct supervision over the routine work of the track forces, relieving the section forces of the large amount of unproductive time formerly required of them in making daily track inspections, and providing the roadmaster with a direct representative among the section forces at all times.

The track supervisor system was put into effect on both the Burlington and the Rock Island in 1931, the Burlington establishing its first unit of the system in April of that year, followed shortly by the Rock Island which established its first unit of the system in August. Subsequently, the system was expanded on both roads, until today it is in effect on approximately 90 percent of the main lines of both roads.

After Careful Investigation

The inauguration of the system on both the Burlington and the Rock Island was brought about following a most careful investigation of possible reorganizations of their track forces for the purpose of affecting sizable economies in carrying out the work of these forces without in any way lowering the general standards of maintenance. The investigation on both roads was prompted by a realization that the serious decline in business then under way throughout the country was more than temporary, and that the increased strength and stability that had been built into their tracks in the years immediately preceding would permit adjustments in organizations and methods, with sizable economies and no reduction in maintenance standards.

The fundamental objectives sought in the track supervisor system included the further lengthening of sections to obtain fewer but larger gangs, overcoming the disadvantages of reducing section gangs to an impractical size; relieving the section forces of the large amount of time spent in patrolling tracks; and the bringing about of closer and more intensive supervision of the various classes of track work. In general, under the system as installed, main line sections were lengthened from 7 or 8 main track miles to 10 or 12 main track miles, depending upon local conditions, and branch line sections were lengthened from 9 or 10 miles to 12 or 15, and in some cases, 20 miles. Roadmasters' territories were also lengthened from 100 to 200 miles of main line to 200 or 300 miles of line, depending upon the type of territory, and track supervisors were appointed with territories including 60 to 70 miles of main line and with jurisdiction over 6 or 7 sections.

Section Forces Relieved of Track Patrolling

This lengthening of sections was made possible largely through relieving the section forces of daily track patrolling. Prior to the adoption of the supervisor system, daily patrolling of main line tracks was considered necessary on both the Burlington and the Rock Island, and this was done by the foreman, accompanied by enough laborers to handle a motor car. This procedure caused the section forces to spend 15 to 25 percent or more of their time unproductively from the standpoint of the actual performance of work, depending upon the lengths of sections, size of gangs and density of traffic. Under the track supervisor system, each supervisor does all of the patrolling for the section gangs under him, in addition to carrying out his other responsibilities, going over his territory in one direction one day and returning the following day.

In automatic signal territory on the Rock Island, track supervisors patrol every week day and are off Sunday and holidays, while in non-automatic signal territory they patrol on Sundays and are off Wednesdays, on which day the section forces patrol their own sections. On the Burlington, the track supervisors patrol every working day and both track supervisors and section forces are off Sundays and holidays. In terminals and extensive yards on this road, the jurisdiction of supervisors is confined to the main line tracks. The roadmasters generally accompany all heavy work equipment or work trains working on their territories, leaving the track supervisors free to supervise routine operations.

Although the section foremen are under the jurisdiction of the track supervisors on both the Burlington and the Rock Island, actual responsibility for the condition of their track has not been taken from the foremen by the track supervisor system. The section foremen are also held responsible for patrol in case of emergencies in which the track might be endangered, such as heavy rains, snowstorms, etc. The track supervisors are not called for work of this kind, but are available when needed and form a quickly available source of experienced supervision for any class of emergency work. On the Burlington, in order that the supervisors may be located quickly throughout any period of the day, their routes are scheduled, where possible, in the same direction daily. This arrangement also keeps the different supervisors well spaced over the road so that they are readily available at any point at any time. For carrying out their routine track patrolling, the track supervisors on both the Burlington and the Rock Island are equipped with light, one-man motor cars.

In addition to their responsibility for patrolling track, the supervisors on both roads visit all the foremen daily, spending as much time with them as is necessary to program their work and to give it proper supervision. Among the special classes of work to which the supervisors are required to give special attention are the spotting of ties for yearly renewals and the handling of such work equipment as ditchers, weed mowers, weed burners, etc., over their territories, except when this equipment is accompanied by the roadmaster. Other duties of the track supervisors on both roads include the filling of switch lamps, except in yards, and the daily inspection of all main line switches. In so far as possible, the supervisors are relieved of all correspondence and administrative duties.

System Effects Large Savings

Large savings have been brought about on both the Burlington and the Rock Island as a result of the adoption of the track supervisor system, these becoming larger as the system became more thoroughly established, when it was found that the number of track laborers per mile of track could be reduced over the number required under the old arrangement. The results on the Rock Island since the establishment of track supervisors indicate monthly savings, depending upon the season, of approximately $25,000 to $30,000. In estimating these savings, no allowance is credited for savings due to reductions in the cost of the operation and maintenance of section motor cars, the retirement of section and tool houses, and the savings in tools furnished, etc., as these are offset in part by the added expense of motor cars for the track supervisors.

Evidence of the economies that are being effected on the Burlington through the adoption of the track supervisor system are shown clearly in a comparison of the force organization of its 454-mile line between Aurora, Ill., and Council Bluffs, Iowa, before the adoption of the system, and at the present time. On this line, there are 413 miles of double track and 41 miles of single track. Nearly all of this track is ballasted with gravel or chatt ballast and occasionally some cinders. The rail in this territory is of 131-lb., 112-lb., 110-lb., and 100-lb. section. The following table presents a comparison of the supervisory maintenance forces before and after the installation of the track supervisor system.

Aurora to Galesburg	*Before track supervisors*	*After track supervisors*
Miles of double track (main line)	124	124
Number of sections	31	22
Average length of section (main-line miles)	8.0	12.0
Average miles of side tracks per section	2.7	3.5
Number of supervisors	...	2
Average length of supervisors' territories (miles of main track)	...	124
Number of roadmasters	1½	1

Galesburg to Council Bluffs	*Before track supervisors*	*After track supervisors*
Miles of double track (main line)	289.4	289.4
Miles of single track (main line)	40.6	40.6
Number of sections	76	63
Average length of section (main-track miles)	8.15	9.82
Average miles of side tracks per section	2.72	3.28
General foremen	1	...
Number of supervisors	...	5
Average length of supervisors' territory (miles of main track)	...	123.9
Number of roadmasters*	5	4

* Note these roadmasters also have considerable branch line territory.

On the territory from Aurora to Galesburg the saving in salaries is estimated at $10,698 per year. On the same basis, establishment of the track supervisor system on the line from Galesburg to Council Bluffs shows a saving of $14,731.20 annually. These figures do not include any credit for a slight reduction in the total number of laborers or credit for tool houses, motor cars, tools, etc. The gross tonnage handled per year between Aurora and Galesburg in the recent years of reduced traffic averaged approximately 8,000,000 westbound and 11,000,000 eastbound, while between Galesburg and Council Bluffs the average annual tonnage handled is 5,900,000 westbound and 5,000,000 eastbound.

That the track supervisor system has proved its efficiency is no longer questioned on either road. In fact, shortly after it was established, it became popular with most of the foremen, who, without the necessity for patrolling, were able to spend more time on other important work. The system is especially popular with the roadmasters, who soon begain to realize that the supervisors were proving valuable assistants by taking responsibility for many details that the roadmaster with a large territory could not otherwise look after efficiently.

Conclusions

(1) The track supervisor system enables the section forces to devote their full time to productive work, thereby increasing their output and effecting considerable economy in the forces necessary to maintain track to a given standard.

(2) It provides closer day-to-day supervision over the co-operation with the foreman, again contributing to increased production and promoting a uniformity of work.

(3) It provides means for training men in supervisory responsibilities and thereby fitting them for appointment as roadmasters.

(4) By relieving the district roadmaster of a large part of the direct supervision of his section foremen, he is permitted to devote more time to the larger special tasks, such

as the supervision of rail gangs, the operation of work trains, etc. This has also made it possible to extend his territory.

(5) By reducing the number of section gangs, a corresponding reduction is effected in motor cars, section tool houses, etc., and in their maintenance.

This report is presented as information.

Appendix B

(4) The Effect of Modern Equipment and Machines on Bridge Gang Organizations and Efficiency

J. S. McBride (chairman, subcommittee), Lem Adams, W. H. Brameld, J. I. Catherman, Armstrong Chinn, C. M. Chumley, F. L. Guy, A. C. Harvey, D. A. Kuebler, C. H. Paris.

Inquiries were sent to 59 railroads and replies were received from 51 of them. As the latter operate approximately 199,000 miles of road, the replies should be representative of the United States and Canada. Of the 51 roads answering the committee inquiry, nine furnished no information, stating they were not in a position to do so; were making studies that would probably lead to the purchase of modern equipment; or had no modern equipment or power tools in use by bridge gangs. Several roads cited the financial condition of the past decade as preventing the purchase of modern equipment.

The information received indicated that the assignment of modern equipment and power tools to bridge gangs varied according to the size of the road and local conditions.

TABLE 1

STEEL BRIDGE GANGS

POWER TOOLS & MACHINES	ROADS																		
	2	3	6	7	9	11	12	17	18	24	26	33	35	36	37	40	41	45	52
Borer	•	•	x	x	•	x	x	•	•	x	x	x	•	•	•	•	•	•	x
Compressor, Air	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Concrete Mixer	•	•	•	x	•	x	•	•	•	•	•	•	•	•	•	•	x	•	x
Crane	x	x	•	•	•	x	x	x	x	x	•	x	x	x	x	•	•	•	x
Drill	•	x	x	•	x	x	x	x	x	x	•	x	x	x	x	x	x	x	x
Eye Bar Shrinkage Equipment	•	x	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	x
Forge, Oil	x	•	•	•	•	•	x	•	•	•	•	•	•	•	•	•	•	•	x
Generator, Lighting Plant	•	x	•	•	•	•	•	•	•	x	x	•	x	•	•	•	•	•	x
Generator, Welding	x	x	•	x	•	x	x	•	x	x	•	•	•	•	x	•	•	•	x
Grinder	•	x	x	•	•	x	x	•	x	x	•	x	•	x	•	•	•	•	x
Gun, Rivet Cutting	x	x	•	•	x	x	x	•	x	•	•	x	•	x	•	•	•	•	x
Hammer, Chipping	•	x	x	x	x	x	x	•	x	x	•	x	•	x	•	x	•	•	x
Hammer, Jack	•	x	•	x	x	x	x	x	x	•	•	x	x	x	x	•	x	•	x
Hammer, Riveting	•	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Hammer Scaling	•	x	•	•	•	•	•	•	•	x	•	x	x	•	x	x	•	•	x
Hoist, Air	•	•	x	•	•	x	x	•	•	x	•	•	•	•	•	•	•	•	x
Hoisting Engine	•	•	•	•	x	x	•	•	•	•	•	•	x	•	•	•	x	•	x
Jacks, Mech. & Roller Type	•	x	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Paving Breaker	•	•	•	x	•	x	x	x	x	•	•	x	•	•	•	•	x	•	x
Pump	•	•	•	x	x	x	•	•	•	•	•	x	x	•	•	•	•	•	x
Punch & Riveter, Combination	•	•	•	•	•	•	•	•	•	•	•	•	•	x	•	x	•	•	x
Reamer	•	x	x	•	x	x	x	•	x	x	•	x	•	x	x	x	•	•	x
Rivet Buster	•	x	x	x	•	x	x	•	x	x	x	x	•	x	x	x	x	•	x
Riveter, Jam	•	•	x	•	•	•	x	•	x	x	•	x	•	x	x	•	•	•	x
Rust Cutting Tools	•	x	•	•	•	•	•	•	•	•	x	x	x	•	•	•	•	•	x
Sand Blast	•	x	•	x	x	•	•	•	•	•	•	•	•	•	•	•	•	•	x
Saw	x	•	•	•	•	x	•	•	•	x	•	x	•	•	•	•	•	•	x
Sprayer	•	•	•	•	•	•	•	•	•	•	•	•	•	•	x	•	•	•	•
Torch, Oxy-Acetylene	•	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Trucks, Auto	•	•	•	•	•	•	•	•	•	x	•	•	•	•	•	•	•	x	x
Winches, Air	•	•	•	•	•	•	•	•	•	x	•	•	•	•	•	•	•	•	x
Wrench, Impact	x	x	•	•	•	x	x	x	x	x	•	x	•	•	•	•	•	x	x

TABLE 2

WOOD BRIDGE & TRESTLE GANGS

POWER TOOLS & MACHINES	ROADS										
	2	6	7	12	17	26	32	35	41	48	52
Bolter	•	•	•	x	•	x	•	•	•	x	•
Borer	x	x	x	x	•	x	x	•	x	•	x
Compressor, Air	•	x	x	x	•	x	x	•	x	•	x
Concrete Mixer	•	•	•	•	•	•	•	•	x	•	x
Crane	•	x	•	x	•	•	•	•	x	•	•
Drill	•	x	•	x	x	x	•	x	x	x	x
Driver, Pile	x	x	•	x	x	•	•	x	x	•	x
Generator, Power	•	x	•	x	•	•	•	x	x	x	x
Generator, Power (On Motor Car)	•	•	•	•	x	•	•	•	x	•	•
Hammer, Jack	•	•	•	•	•	x	•	x	x	•	x
Hammer, Portable Electric	•	•	•	•	•	x	•	•	•	•	•
Hoisting Machine	•	•	•	•	•	•	•	x	•	•	x
Saw, Chain	•	x	•	x	x	x	x	•	x	•	x
Saw, Circular	x	x	x	x	x	x	x	x	x	•	x
Paving Breaker	•	x	•	•	•	•	•	•	x	•	x
Torch, Oxy-Acetylene	•	x	•	•	•	•	•	x	x	•	x
Trucks, Auto	•	•	•	•	•	•	•	•	•	x	•

TABLE 3

CONCRETE GANGS

POWER TOOLS & MACHINES	ROADS								
	2	5	12	17	26	40	41	45	52
Compressor, Air	•	x	x	x	•	•	x	x	•
Concrete Mixer	x	x	x	x	x	x	x	x	x
Crane	•	•	•	•	•	•	x	•	x
Grouting Machine	•	•	•	•	•	•	•	x	•
Gun, Cement	•	•	•	•	x	•	x	x	•
Hammer, Bush	•	•	x	•	•	•	x	x	•
Hammer, Chipping	•	•	x	•	•	•	•	x	•
Hammer, Jack	•	x	x	x	x	•	x	x	•
Paving Breaker	•	x	x	x	x	•	x	x	•
Pump	•	•	x	x	x	x	x	x	x
Saw, Circular	•	•	•	x	•	•	•	•	•
Truck, Auto	•	•	•	•	•	•	•	x	x
Vibrator	•	•	x	•	•	•	•	x	x
Winch	•	•	•	•	•	•	x	x	•

TABLE 4

PAINT GANG

POWER TOOLS & MACHINES	ROADS																				
	2	6	9	11	12	13	24	26	29	32	33	34	35	38	40	41	45	46	48	49	52
Brush, Wire	x	x	x	x	x	x	•	x	•	x	x	x	x	•	•	x	x	•	•	•	x
Compressor, Air	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	•	x
Compressor, Air(On Motor Car)	•	•	•	x	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Grinder	•	x	•	•	x	x	•	•	•	•	x	•	•	•	•	•	•	•	•	•	•
Hammer, Chipping	x	x	•	x	•	•	x	•	x	•	x	x	x	•	•	•	x	•	•	•	x
Hammer, Scaling	•	x	•	x	•	x	x	•	x	x	x	•	x	•	•	x	•	•	•	•	x
Hoist, Scaling	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	x	•	•	•	•
Sand Blast	•	•	•	x	x	•	•	x	•	•	•	•	•	x	•	•	x	•	•	•	x
Sprayer	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Trailer, Auto(Living Quarters)	•	•	•	•	•	•	•	•	•	•	•	x	•	•	•	•	•	•	•	•	•
Truck, Auto	•	x	x	•	•	•	•	•	•	•	•	x	•	•	•	•	x	•	•	•	x
Vibrator	•	•	•	•	•	•	•	•	•	•	x	•	x	•	•	•	x	•	•	•	•

TABLE 5

COMBINATION BRIDGE GANGS

POWER TOOLS & MACHINES	ROADS								
	12	16	[illegible]	30	32	33	37	42	46
Borer	x	x	x	•	x	x	x	•	•
Compressor, Air	x	x	x	x	x	x	x	•	•
Concrete Mixer	x	x	•	x	x	•	•	•	x
Concrete Mixer on Flat Car with Water Tank & Material Bins	•	•	•	•	•	•	x	•	•
Crane & Pile Driver	x	x	x	•	x	x	x	•	•
Drill	x	x	x	x	x	x	•	x	•
Generator, Power	x	x	•	•	•	•	•	x	•
Generator, Welding	x	•	x	•	x	•	•	•	•
Grinder	x	x	x	•	x	•	•	•	•
Hammer, Chipping	x	x	x	•	x	x	•	•	•
Hammer, Jack	x	x	x	x	x	x	x	•	•
Hammer, Riveting	x	x	x	x	x	x	•	•	•
Hoist, Air	x	•	x	•	x	•	•	•	•
Magnet with crane	•	x	•	•	•	•	•	•	•
Paving Breaker	x	x	x	x	x	x	x	•	•
Pump	x	•	•	x	x	x	•	•	•
Reamer	x	•	•	x	x	x	•	•	•
Rivet Buster	x	•	x	•	x	x	•	•	•
Riveter, Jam	x	•	x	•	x	x	•	•	•
Saw, Chain	x	•	x	•	•	x	•	•	•
Saw, Circular	x	x	x	•	x	•	•	x	•
Shovel, Crawler	•	•	•	x	•	•	•	•	•
Sprayer	•	•	•	•	•	•	x	•	•
Torch, Oxy-Acetylene	x	x	•	x	x	x	x	•	•
Truck, Auto	•	•	•	•	•	•	•	x	•
Vibrator	•	•	•	•	•	•	x	•	•
Wrench	•	•	•	•	•	•	•	•	•

Some roads have specialized gangs for each type of bridge work; others have combination bridge gangs for various types of work and the tools on these roads are assigned accordingly. Still other roads assign their equipment to divisions, districts or the system for the use of all bridge gangs as required. Some of the roads that assign equipment and power tools to certain gangs, assign other equipment to the system or some definite territory for the use of various gangs as needed.

Tables 1 to 6 list the power tools and machines of the various roads according to the assignment of this equipment. While some of the equipment listed may have been in use for years, it has been included with the thought that much of it is of the modern type or has been modernized, as is the practice of many roads with some of their older equipment.

Bridge Gang Organization

Road No. 2 states the purchase of modern tools has extended over a period of several years and during this time its organization has undergone many changes due to traffic conditions and the abandonment of branch lines, so that it is difficult to say just what changes have been due to the use of power tools, but it is known that a very considerable saving has resulted.

Information furnished indicates a tendency toward the use of highway trucks in bridge gang work, eight roads are using trucks assigned to bridge gangs and three of these and six others have assigned trucks to definite territories for the use of all gangs. The use of these trucks is more general in paint gangs.

Road No. 6, in addition to using highway trucks on a terminal division, has mounted two gas-electric power units on two pneumatic-tired trailers for hauling behind a truck. These power units are used by two or three bridge crews assigned to the maintenance of timber trestles, timber deck bridges and other wood structures on the division.

Road No. 26 reports that from the time its line was constructed until about two years ago its bridge gangs were sent to the location of the work in outfit cars, which

TABLE 6

ASSIGNED TO DIVISIONS, DISTRICTS OR SYSTEMS

POWER TOOLS & MACHINES	ROADS																															
	3	4	5	6	7	8	9	11	12	13	14	15	18	23	31	33	34	35	36	37	38	39	40	41	42	44	47	48	49	51	52	56
Boiler, Steam	•	•	•	x	x	x	•	x	x	•	•	x	x	•	x	•	•	x	•	•	•	x	•	x	x	•	•	•	•	x	x	•
Bolter	x	x	•	•	•	•	•	•	x	•	•	x	•	•	•	•	•	•	•	•	x	•	•	•	•	•	•	•	•	x	x	•
Borer	x	x	x	•	x	x	•	x	x	•	x	x	x	x	x	•	•	•	x	x	x	•	x	x	•	•	x	•	x	x	x	x
Brush, Wire	•	x	•	•	x	x	•	•	x	•	•	x	x	x	x	•	•	x	•	•	•	•	•	•	•	•	•	•	•	x	x	x
Clay Digger	•	•	•	•	•	•	•	x	x	•	•	x	x	•	•	•	•	•	•	•	•	•	•	•	•	x	•	•	•	•	x	•
Compressor, Air	x	x	•	x	x	x	x	x	x	x	x	x	x	x	x	•	•	•	x	x	x	x	x	x	x	x	x	•	x	x	x	x
Concrete Mixer	x	x	•	x	x	x	x	x	x	x	•	x	x	x	x	x	x	x	x	x	x	x	•	x	x	x	x	•	x	x	x	x
Crane	x	x	x	x	x	x	x	x	x	x	•	x	x	x	x	x	x	x	•	x	•	x	x	x	x	x	x	x	•	x	x	x
Dapper, Timber	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	x	•	•	•	•	•
Derrick	•	x	•	•	•	x	•	•	x	•	•	x	x	•	x	x	•	•	•	•	•	•	•	•	x	x	•	•	•	•	x	x
Drill	x	x	•	x	x	x	•	x	x	x	•	x	x	x	x	•	•	•	•	x	•	•	•	•	•	•	x	•	•	x	x	x
Driller Core	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	x	•	•	•	•	•	•	•	•	•	•	•	•
Driver, Pile	•	x	•	x	x	x	x	x	x	x	•	x	x	x	x	x	x	x	x	x	•	x	x	x	x	x	x	•	•	x	x	x
Forge, Oil	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	x	•	•	•	•	•
Generator, Light Plant	x	•	•	x	•	•	•	x	•	•	•	•	•	•	•	x	•	x	•	•	•	•	x	•	•	•	•	•	•	•	x	x
Generator, Power	•	x	•	x	•	•	•	•	x	x	•	•	x	•	•	•	•	•	•	•	•	•	x	•	x	•	•	•	x	x	x	x
Generator, Welding	•	x	•	x	•	x	•	•	x	•	•	x	•	•	x	•	•	•	•	•	•	•	x	•	•	•	•	•	•	x	x	x
Grinder	•	x	•	•	x	x	•	•	x	•	•	x	x	x	x	•	•	•	•	•	•	•	•	•	•	•	•	•	x	x	x	x
Grouting Machine	•	x	•	x	•	•	•	x	•	•	•	•	•	•	•	x	•	•	•	•	•	•	•	•	•	•	•	•	•	x	x	•
Gun, Cement	•	x	•	x	x	x	•	x	x	•	•	•	x	•	•	•	•	•	•	•	•	x	x	•	x	x	•	•	•	x	x	x
Hammer, Chipping	•	x	•	•	x	x	•	•	x	•	•	x	x	x	x	•	•	x	•	•	•	•	•	•	x	•	x	•	•	x	x	x
Hammer, Jack	•	x	x	x	x	x	•	x	x	•	•	x	x	x	x	x	•	x	x	x	x	x	x	x	x	•	x	•	•	x	x	x
Hammer, Riveting	•	x	x	•	•	x	•	x	x	•	•	x	•	•	x	x	•	x	•	•	•	x	•	x	•	x	x	•	x	x	x	x
Hammer, Scaling	•	x	•	•	•	x	•	•	•	•	•	x	x	x	x	•	•	x	•	•	•	•	•	•	•	•	•	•	•	x	x	x
Hammer-Sheet Pile	•	•	•	•	•	•	x	•	•	•	•	•	•	•	•	•	•	•	•	x	•	•	•	•	•	•	•	•	•	•	x	x
Hoist, Air	•	x	•	x	x	•	•	x	x	•	•	x	•	x	•	•	•	•	•	•	•	•	•	•	•	•	•	•	x	•	x	•
Hoisting Engine	•	x	•	•	•	•	x	x	x	•	•	x	x	•	x	x	•	•	•	x	•	x	•	•	x	x	•	•	•	•	x	•
Locomotive-Gasoline	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	x	•	•	•	•	•	•
Paving Breakers	•	•	x	x	x	x	•	x	x	x	•	x	x	x	x	x	•	•	x	•	x	•	x	•	x	x	x	•	x	•	x	x
Pump, Concrete	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	x	•	•	•	•	•	•	•	•	•	•	•	•	•	•	x	•
Pump, Jet	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	x	•	•	•	•	•	•	•	•	•	•	•	•
Pump, Water	x	x	•	x	x	x	•	x	x	x	•	x	x	•	x	x	•	x	•	x	•	x	•	x	x	x	x	•	x	x	x	x
Reamer	•	•	•	•	•	x	•	•	x	•	•	x	•	•	x	•	•	•	•	•	•	•	•	•	•	•	•	•	•	x	x	x
Rivet Buster	•	x	•	•	x	x	•	x	x	•	•	x	•	•	x	•	•	•	•	•	•	x	•	x	•	•	•	•	•	x	x	•
Sand Blast	x	x	•	x	x	x	•	•	•	•	•	x	•	x	•	•	•	•	x	•	•	x	x	•	•	•	x	•	•	x	x	x
Saw, Chain	•	•	•	x	x	x	•	x	x	x	x	•	x	•	•	•	•	•	•	•	x	•	x	x	x	•	•	•	x	x	x	x
Saw, Circular	x	x	•	x	•	x	•	x	x	•	x	x	x	x	•	x	•	x	•	x	x	•	x	•	x	x	•	•	x	x	x	x
Sprayer, Paint	x	x	•	•	•	x	x	•	x	•	•	x	x	x	x	•	•	x	•	x	•	x	•	x	x	x	x	•	•	x	x	x
Torch, Oxy-Acetylene	•	x	•	x	•	x	x	x	x	x	•	x	x	x	x	•	•	x	x	•	•	x	•	•	x	•	x	•	•	x	x	x
Trailer, Truck	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	x	•	•	•	•	•	•	•	•	x	•	•	•	•	•	x	•
Truck, Auto	•	•	•	x	•	•	•	x	•	•	•	•	x	•	•	•	•	•	•	•	•	•	x	x	•	•	x	•	•	•	x	•
Vibrator	x	x	•	•	x	•	•	•	x	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	x	•	x	•	x	•
Wood Work Machine, Portable (Comb.Gainer,Cross Cut & Rip Saw)	•	•	•	•	•	•	•	•	•	x	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Wrench	•	x	•	•	•	•	•	•	x	•	•	•	x	x	•	•	•	•	•	•	x	•	x	x	•	•	•	•	x	x	x	•

was long considered an unsatisfactory and expensive method for which there was no alternative. With the development of the auto-truck, to its present efficiency it recognized the possibility of eliminating the use of outfit cars by furnishing such gangs at certain important points or terminals with auto-trucks and trailers. Such trucks are now in use at eight important terminals on the four eastern divisions and at three similar terminals on the western divisions. This highway equipment is used for transporting terminal crews and material to jobs that can be reached without great loss of time. The use of modern power machinery and equipment in the bridge gangs, to the extent that such program has been authorized, has not resulted in any change in bridge gang organization so far, but has brought about a reduction in the number of men in the usual bridge gang from an average of 14 to 16 men, to between 8 and 11, mostly because power machines handle the heavy work, thus making the smaller crews more economical as they accomplish as much or more work in less time than the larger crews previously employed.

Road No. 34, in addition to a highway truck, uses a trailer as sleeping quarters for a crew engaged in painting depots and other station structures.

Road No. 48 has assigned three highway trucks to bridge gangs working out of terminals. These trucks are used by terminal gangs in making bridge and building repairs, both in the terminals and on the line within reasonable trucking distances, thereby eliminating the necessity of moving bridge outfits to the site. The trucks are also available for emergency needs when immediate train service is not available.

Three roads state that the acquisition of equipment has resulted in the reduction of the number of gangs required rather than number of men in a gang, while three others report reductions in force, without stating how the reductions were made, one of the roads reporting reductions of about 25 percent.

Two roads report that modern equipment has resulted in a reduction in the number of laborers in the gangs and an increase in the number of mechanics. A third states that size of its gangs has been reduced, the savings being made in skilled laborers.

Requires Careful Programming

One road commented as follows: "We have not found that the use of these machines and equipment requires any special changes in bridge gang organization, although it does require more careful programming of the work, more thorough training of the foremen, and more general supervision to see that the equipment is being used at all times to the best advantage."

Another reply states: "The use of mechanical tools and equipment in bridge gangs demands a better trained organization and more skilled workmen. This is particularly true of the foreman in charge of the gang, who must know the capabilities of his men and how to properly use tools and equipment furnished him."

According to the replies of 13 roads, no change in bridge gang organization is deemed necessary because of the use of power tools and equipment, although two report that more work can be done with this equipment, and another has added certain work to bridge gangs that was not performed by these gangs prior to the acquisition of this equipment.

Road No. 11 formerly framed bridge timbers in the field but has now established a central plant adjacent to a treating plant where bridge timbers are framed prior to treatment.

On Road No. 13 a bridge gang formerly preframed bridge timbers at the treating plant by hand methods. The officers feel that the property is not of sufficient size to justify a central plant, and accordingly has purchased a portable woodworking machine which is a combination gainer, cross-cut saw and rip saw. With this machine the time of the bridge gang required for preframing has been reduced to an extent that enables this gang to be employed on bridge work a greater part of its time.

Road No. 46 reports that it uses creosoted timbers for its bridges, and as these are preframed, but little work is done at the bridge site that would ordinarily require power machinery in the field.

One road points out that, "having mechanical tools and equipment in a bridge gang undoubtedly increases the efficiency as well as the morale of the gang, and tends to raise the standard of workmanship, all of which is a factor in reducing the number of potential personal injuries in bridge construction work."

Efficiency of Bridge Gangs

The effect of modern equipment and machines on the efficiency of bridge gangs is shown by the savings accomplished through the use of certain machines as indicated by the following excerpts from the replies received:

Road No. 8.—Paint spraying outfits in some instances result in saving of 50 percent as compared with hand work. The comment is made, however, that there are cases where, when the job is small and it includes considerable painting of lattice members, the work can be done as cheaply by hand.

Road No. 11.—The framing of timbers in the field formerly cost $17.50 per M. ft.b.m. This cost has been reduced to $5.36 per M ft.b.m. by preframing the timbers at a central plant adjacent to the treating plant. The central plant is equipped with:

- Planer
- Boring machines
- Gaining machine
- Band saw
- Cut-off saws
- Rip saw
- Crane (for handling timbers)

The reply adds that it is known from general reductions in bridge and structures expenses that such equipment has resulted in appreciable economies.

Road No. 13.—This year we purchased a portable woodworking machine and electric generator for preframing bridge timbers. This machine and the generator are moved from place to place in the seasoning yard for framing prior to treatment. So far this year, with the gainer attachment on this machine, we have dapped some 1,700 ties for steel bridges, resulting in a reduction of 55 percent in the man-hours required for handling ties from piles to machine, dapping of ties, handling ties from the machine, and the moving of the machine from pile to pile, as compared with performing the same work by hand. The labor saving has been 24 cents per tie. Work with this machine is of a higher grade than can be done by hand.

Road No. 16.—With the use of electric drills we figure a saving of 50 percent in labor on such work as drilling of chord-bolt holes.

Road No. 17.—A study in 1933 of the labor cost of a six-span, 82-ft. pile trestle in main track with hand tools, as compared to the labor cost on a trestle of the same length in a storage track, using one power chain saw, one power circular saw and two power drills, showed that the cost of labor using the power tools was $29.06 less than with hand tools. The average time involved in various operations, based on upward of 35 tests of each operation is shown in the following table:

	Time Required		*Men Used*		*Man-Minutes Per Operation*	
Operation	*By Hand*	*With Power*	*By Hand*	*With Power*	*By Hand*	*With Power*
Sawing piling—average 14″ diameter	7′-40″	1′-31″	2	3	15′-20″	4′-33″
Saw 8″x16″ stringer	3′-29″	0′-57″	2	2	6′-58″	1′-54″
Saw 10″x18″ stringer	4′-22″	1′-15″	2	2	8′-44″	2′-30″
Bore packing rods—4—8″x16″	6′-42″	1′-57″	1	2	6′-42″	3′-54″
Bore packing rods—3—10″x18″	6′-15″	1′-50″	1	2	6′-15″	3′-40″
Bore drifts—16″ stringers	3′-59″	0′-56″	1	1	3′-59″	0′-56″
Bore 14″x14″ cap drifts	3′-19″	1′- 7″	1	1	3′-19″	1′- 7″
Bore brace bolts	3′-42″	1′-12″	1	2	3′-42″	2′-24″
Saw dap guard rail—average 1″	0′-18″	0′- 5″	2	2	0′-36″	0′-10″
Bore guard rail spikes	0′-36″	0′-11″	1	1	0′-36″	0′-11″
Bore guard rail bolts	1′-46″	0′-35″	1	1	1′-46″	0′-35″
Bore recess washers ¾″ deep	0′-27″	0′-18″	1	1	0′-27″	0′-18″
Bore line spikes	0′-50″	0′-15″	1	1	0′-59″	0′-15″

The reply stated also that, in the case of concrete and steel gangs, the increase in output with power tools, compared with hand work, is greater than in wood bridge work.

Road No. 18.—Tests made before purchasing paint spraying machines indicated a saving of about 40 percent in labor but no saving in material. Tests made to compare hand drilling with machine drilling indicated that six to eight times as much work could be done with a machine as with hand drills. Test with an electric-operated cross-cut saw indicated that two men with one machine could cut off as many piling in one hour as two experienced bridge men could cut off in eight hours with a hand saw.

Road No. 26.—While we are fully convinced that the use of highway trucks and trailers for transporting bridge and building crews and tools is more economical than the use of outfit cars, we do not at this time have any particular studies to submit in support of such belief.

However, we have information to the effect that on one important eastern railroad, the use of trucks for bridge and building maintenance during 1938 resulted in savings on one division as follows:

Saving due to the use of a truck in a terminal	$ 1,916
Another truck, by eliminating three helpers, saved in labor	3,300
At two terminals on same division use of one-ton pickup trucks saved in labor	2,400
On the same division use of electric and air equipment and tools (other than locomotive and burro crane) is estimated to have saved	5,800
Total estimated saving on one division (1938)	$13,416

On another eastern division, the use of a highway truck by bridge and building crews at an important terminal with 267 day's service during 1938 is estimated to have saved $1,107. On another division in the western part of North Dakota, the use of a highway truck assigned to bridge and building crews (209 day's service) is estimated to have saved during 1938, $1,733. At a Montana terminal, a highway truck in similar use with 200 day's service from March to December, 1938, is estimated to have saved $2,612. On a western division in the State of Washington, the use of modern bridge repair equipment is estimated to show a saving of 35 to 45 percent compared with previous costs, offset by charges amounting to 10 percent covering rental, depreciation and maintenance of equipment.

The saving as a result of the use of auto trucks and trailers is brought about by a reduction in the force required for handling material compared with that employed previously. Before the trucks were acquired it was necessary to employ a push car to handle considerable material, requiring a greater amount of help. Also, where the maintenance gangs are involved, the men are now hauled to the job in trucks, whereas previously it was necessary to furnish outfit cars in handling them from point to point, in addition to moving the men on motor cars each morning and evening from the outfit car location to the work. These items constitute the major portion of the saving. There is also a saving (that is rather hard to measure) as a result of the quicker delivery of materials and therefore less delay to the crew in waiting for material.

The savings quoted represent savings in labor only, and no consideration has been given to interest, depreciation, or the cost of operating trucks or trailers.

Road No. 34.—In 1936 we cleaned and painted Bridge "A", a 103-ft. span, by hand, the expense for labor being $262, and for material $53.37, or a total cost of $315.37. In 1938 we painted Bridge "B", a 103-ft. span, using an air compressor, with paint guns, brushes and chippers all operated by air furnished by the compressor, and the costs were as follows: Labor $139.61; material $49.72, or a total of $189.33. This indicates a total saving of $126.04.

In 1936 we painted Depot "A" by hand with a labor cost of $123.56, and used 15 gal. of paint. In 1938 we painted Depot "B", which we believe compares favorably in size with the Depot "A", using the compressor. The labor charge amounted to $66.90, and we used 11 gal. of paint.

In 1936 we also painted Depot "C" by hand; the labor charge was $170.50, and we used 16 gal, of paint. In 1938 we painted Depot "D", using the compressor and paint equipment mounted on portable truck; the labor charge was $32.45, and we used 18 gal. of paint. We painted Depot "E" with a labor cost of $33.70, and 14 gal. of paint. For Depot "F" the labor charge was $44.00, using 16 gal. of paint. These last three depots, we feel, compare quite favorably with Depot "C" and show a very large saving in labor charges.

Road No. 37.—Our observations as to saving to be effected by use of modern tools include the following:

Reduction of one to three men while placing concrete by using a concrete vibrator.

Two men will drive as many lag screws with an air motor as eight men can drive by hand.

In bracing timber bents one man can apply bolts in holes bored by three men if the holes are bored by hand, but if an air motor is used to bore the holes, one man can bore enough holes to keep three men busy applying the bolts.

One man can spray paint faster than five men can paint by hand.

By using a concrete mixer car, concrete in small quantities can be placed with a labor saving of 40 percent compared with the cost which would be incurred by setting up a plant at the site.

One man with a jack hammer can do as much work as five men with hand tools.

An air compressor can be used to such advantage as to save its first cost in one year's time if it is accompanied by the proper tools.

Road No. 38.—We recently purchased three small flexible-shaft outfits, each equipped with a boring machine and a wrench, which we are now using in a trestle reinforcement program where we are adding one stringer under each rail to open-deck trestles. So far two men working with each of these machines perform about what six men would do on that particular kind of work, that is, boring horizontal holes for packing bolts and taking off and putting on nuts.

Road No. 45.—Annual savings through the use of power equipment and tools, as follows:

CHAIN SAW ON HEAVY WORK ON TRESTLES AND DOCKS

Chain Saw			*Hand Operation*	
Cost		$650	4 men—40 min.	
Production	2 men—15 min.		100 days	
Working period	100 days		5 men (2 carpenters & 3 helpers)	$2,648
Wages	2 men	$1,088		
Interest—6%		39		
Depreciation—10%		65		
Annual overhaul—10%		65		
Supplies		52		
Running repairs		5		
Total		$1,314		$2,648
Actual use of saw assumed half time				
Annual saving		$1,334		

PORTABLE ELECTRIC WELDER USED IN REPAIRS AND REINFORCING STEEL VIADUCTS

Welder			*Bridge Hand Work, Fabricated Material and Rivets*	
Cost		$1,500		
Working period	240 days		240 days	
Wages	1 welder	$1,670	1 foreman	$ 2,525
Wages	1 helper	1,133	6 iron workers	9,331
Interest—6%		90	3 helpers	3,398
Depreciation—10%		150		
Annual Overhaul—10%		150		
Supplies		320		
Running repairs		160		
Material		......		560
Total		$ 3,673		$15,814
Annual Saving		$12,141		

CONCRETE MIXER

Concrete Mixer			*By Hand (Estimated)*	
Cost		$700		
Working period	120 days		120 days	
Wages	1 mason	$ 758	1 mason	$ 758
Wages	1 helper	566	4 helpers	2,264
Wages	4 laborers	1,843	16 laborers	7,373
Interest—6%		42		
Depreciation—10%		70		
Annual overhaul—10%		70		
Supplies		60		50
Running repairs		25		
Total		$3,434		$10,444
Annual saving		$7,010		

Road No. 48.—Using electric drills, two men were able to drill 220 brace-bolt holes in 14 man-hours. This work included moving of staging from one bent to another.

Where it was not necessary to move staging, the same two men were able to drill 400 brace-bolt holes in 14 man-hours. Hand drilling 220 bolt holes, including moving the staging, required 37 man-hours and hand drilling without the necessity of moving staging resulted in boring 220 brace-bolt holes in 37 man-hours.

Our test of running up nuts with the electric wrench was made in tightening guard-rail bolts. In this case, we used one man with a hand wrench to hold bolts and two men equipped with electric wrenches. The three men were able to run up the nuts on 500 guard-rail bolts in 24 man-hours. Compared with this, it required 90 man-hours to run up the same number of nuts by hand.

Gangs are equipped with a portable electric 1,500-watt generator, two electric drills and two electric reversible wrenches. This equipment cost approximately $700 and on a standard gang with the average amount of drilling and bolt tightening, we find an annual saving of approximately $1,000.

The following test of the use of a crane in the construction of wooden trestles may be of interest. The test was conducted in connection with the setting of caps on new bents after the cut-offs had been made. Using a crane, six bridge men and one crane operator placed 25 caps using 10 man-hours. In placing an equal number of caps by hand, using a hand-operated winch mounted on a push car, 96 man-hours were required. A proportionate increase in labor efficiency was found in placing stringers.

Paint gangs are equipped with a portable air compressor and two paint guns. With the normal amount of work performed by these gangs, this equipment, costing approximately $800, results in an annual saving of $900.

We have three trucks assigned to bridge gangs working out of terminals. These trucks cost between $1,100 and $1,600 each and are used by the terminal gangs in making bridge and building repairs, both in terminals and on the line within reasonable trucking distances, thereby eliminating the necessity of moving bridge outfits to the site. The use of these trucks results in an average saving of $2,200 annually.

General Comments

One road asserts that: "On some jobs the saving has been as much as 25 percent. In many cases the cost of a particular tool has been saved on one job."

Another road states: "By reason of securing arc-welding machines and other bridge gang equipment, we have been able to speed up repair and strengthening work on steel bridges as compared with doing work by drilling holes and riveting."

Another road reports that: "From close observation and occasional field checks on single jobs, we have no hesitation in saying that there is no question but that the saving of power tools for bridge and building gangs over the older methods is considerable." A fourth road adds: "We do not have any studies at this time showing the savings in labor accomplished, but practically all the savings are visible while the work is in progress."

One road reported: "It is difficult to imagine how some of the work could be done without machinery, such as pile driving, steel bridge erection, pumping, mixing concrete, etc."

Four roads declare that they were sure that equipment has resulted in savings in labor. Three others report that power tools speed up the work and enable the jobs to be completed in shorter time. Still another road advises that such equipment increases the efficiency of the gang to a considerable degree and allows it to accomplish various forms of work which it was not practical to do under the old methods.

Many roads, no doubt, have not been able to make studies of savings in labor resulting from the use of modern equipment for the same reason as expressed by an officer of one system: "The majority of roadway machine and power tool equipment was acquired a year or two prior to and during the first years of the depression. Reductions in clerical and accounting forces have made it impossible to carry on any cost studies since that time. Of course, we know simply as a matter of observation and from the reports of our foremen and maintenance supervisors that substantial savings are accomplished, just what those savings amount to in dollars and cents and the unit basis that might be used for comparison, we are not able to say."

One system announces that it is well satisfied with the results secured from modern equipment and that its forces like to use these tools, but adds a note of caution: "It is quite necessary to hold down their enthusiasm for the tendency is to provide more equipment than can be worked consistently, due to the fact that a large majority of maintenance work consists of small jobs."

Conclusions

1. The effect of modern equipment on bridge gang organization shows no definite trend. The varying results are:
   (a) No change in organization.
   (b) Reduction in the number of gangs.
   (c) Reduction in size of gangs.
   (d) Reduction of laborers and increase of mechanics.

2. It is possible, where no change in organization was found necessary, that failure to make changes may be explained by:
   (a) Reduction in forces during the depression made necessary the acquisition of modern equipment to increase the output of bridge gangs.
   (b) Acquisition of equipment over a period of years when changed traffic and other conditions necessitated changes in organization, so that it is difficult to ascribe such changes definitely to modern equipment.

3. Modern equipment tends to raise the standard of workmanship and requires:
   (a) A better trained organization.
   (b) Closer supervision in programming work and measures to insure that equipment is being used to the best advantage at all times.

4. Preframing of bridge timbers at treating plants has resulted in a reduction of field work by bridge gangs.

5. The use of highway trucks by bridge gangs has resulted, in some cases, in changes in methods by which men and material are handled to the job and in the elimination of the use of outfit cars.

6. The efficiency of bridge gangs is increased because modern equipment enables them to perform certain operations in less time than the work could be done by other methods. This increased efficiency will vary on different phases of bridge work.

7. The economical justification of modern equipment depends upon the length of time such equipment can be kept in use each year.

The report is presented as information with the recommendation that the subject be discontinued.

Appendix C

(8) Labor Economies Which May Be Effected Through Revision of Operating and Maintenance of Way and Structures Rules

F. S. Schwinn (chairman, subcommittee), L. L. Adams, C. W. Baldridge, C. M. Chumley, E. A. Craft, H. T. Livingston, E. H. McIlheran, A. E. Perlman, R. L. Sims, H. M. Stout, C. R. Wright.

Your committee has interpreted this assignment as requiring a study of such rules as are common to all railways and which, in their application, are found to result in an unjustifiable reduction in work performance. The maintenance of way and structures rules of a number of representative railways have been reviewed and while the wording varies, they all contain rules covering flagging requirements and governing the operation of motor and other track cars which are substantially as follows:

FLAGGING REQUIREMENTS

(A) Trains are to be expected at any time and from either direction on any track. Foremen must not assume that a train may not come for any certain time or act under the assurance of any person to that effect, but must at all times provide protection with proper signals as per Rule —, etc.

(B) When track is unsafe or before obstructing track or in any way rendering it unsafe for passage of trains at full speed, a flagman must be sent in each direction a sufficient distance to insure full protection, etc.

OPERATION OF MOTOR CARS, ETC.

(A) Track cars must be removed from main track when not in use.

(B) Where view is obscured account curvature, flagman must be sent ahead.

(C) Where means are available information as to train movements must be obtained from the train dispatcher.

It is generally accepted practice to apply and enforce these or similar rules without exception, and no distinction is made in their application or enforcement as between heavy traffic primary lines, lighter traffic secondary lines and very light and irregular traffic branch lines. With few exceptions, it is also the practice to conduct train operation with the understanding that maintenance forces will provide protection at all times for themselves and their work in the manner contemplated by these rules.

On the majority of railroads, there are many secondary and branch lines having not more than one regularly scheduled train movement in each direction during daylight hours when maintenance forces are at work; and, frequently, all regular scheduled trains on such lines are operated at night. Extra train movements will probably not occur on the type of lines here considered more than a few times per year and seldom more often than once or twice per month.

Your committee feels that every requirement of safety can be met without the necessity of incurring the losses which result from the enforcement without exception of these flagging and motor car rules. It should not be necessary to provide flagging protection when not actually needed or to remove a section motor car from the track. probably a dozen times in one day, when only two or less scheduled train movements are operated during the working hours. A very simple means of eliminating such losses may be accomplished by issuing train orders holding all extras at the terminals of these unimportant lines during the regularly assigned daytime working hours of maintenance forces or by the issuance of permanent time-table instructions prohibiting the operation of extra trains unless preceded by flag. Should the unexpected operation of an extra train become imperative even this may be undertaken with safety by sending a flagman on a motor car in advance of such a train.

A careful analysis was made of the performance on eight representative railroads, one eastern, three southern, one western and three southwestern, having a combined mileage of 32,968. Of this mileage, 7,966 miles, or 24 percent of the total, could be classed as light traffic branches, districts or subdivisions having not more than one scheduled train movement in each direction during the normal daylight working hour assignment of maintenance forces. On these lines, the present normal working force employs 6,213,595 man-hours annually in the maintenance of track and bridges. Careful estimates were made of the unproductive man-hours and it was found that 2.8 percent of the total was used in observing the flagging rules and 2.6 percent of the total was used in observing the rules governing the operation of motor cars. These observances of rules resulted in the loss of 333,913 man-hours per year which might have been employed in productive work and represented an annual payroll expense estimated at $155,788. This is equivalent to $19.56 per mile of light traffic lines and $4.73 per mile of the total operated mileage. The average length of track section involved was 15.3 miles and the loss per section was $299 per year. Your committee has endeavored by means of a questionnaire to secure similar information from a larger number of railroads but has been unsuccessful in this attempt. However, it is felt that the results obtained in analyzing the records of these eight railroads may be considered as reasonably representative and the annual payroll expense of observing the rules referred to is probably very near to $20 per mile of light traffic line operated.

Several maintenance officers have written the committee in opposition to any change in the basic rules previously quoted. Some others object to the Association sponsoring any rules governing the maintenance of way and structures and this view is also held by a considerable portion of the Association membership. On the other hand, some who have been approached have expressed an appreciation of the possibilities for making economies by a properly safeguarded liberalization of the rules your committee has quoted, and in the case of at least one large system, the flagging rules are varied for different types of main track and for occasions when working under train-order protection.

Your committee has given careful consideration to the divergent views and expressions received from a total of 18 large railroads. As a result of this analysis, we feel that:

(a) Revisions of the more or less common and standard rules of maintenance of way and structures departments governing flagging and operation of track cars are not desirable.

(b) Certain economies in labor can be made by eliminating the unproductive time lost through compliance with these rules under all circumstances and these savings can be achieved through the issuance of appropriate train orders or by special operating or time-table instructions and furnishing interested maintenance forces with copies of such orders or instructions.

This report is presented as information.

Appendix D

(9) Economies in Labor Resulting From the Reduction in Track Patrol Made Possible Through Improvements in Track Conditions

F. J. Bishop (chairman, subcommittee), Lem Adams, C. W. Baldridge, W. H. Brameld, J. I. Catherman, R. R. Cummins, G. H. Harris, A. C. Harvey, D. A. Kuebler, G. M. Magee, C. H. Paris, H. M. Stout.

To develop the necessary information on methods of patrolling track by various railways, a questionnaire was prepared and used to obtain pertinent facts as to patrol practices. Much of the information was obtained by personal contact of the subcommittee members with the chief maintenance officers of the various roads. Complete data were obtained from 32 railroads covering 164,000 miles of line. All sections of the country are represented and probably every type of track patrol or method of track inspection has been covered. The replies to the questionnaire have been condensed for study in Table 1, entitled "Track Patrol Methods Used by Principal Railways".

The tabulation shows general practices and does not preclude variations to suit conditions on parts of the roads supplying the information. The data assembled pertain principally to track patrol by section forces or others specifically charged with the duty of inspecting track and roadbed periodically to insure the safe passage of trains. The report does not attempt to cover incidental and occasional inspection of track by supervisory forces, signalmen, bridgemen and other maintenance of way employees. Practically all roads expect their maintenance of way employees, when going over the track, to observe conditions, remove hazards or protect trains from them and report defects to the proper person for correction.

Safety of track is of first importance on all railways and no patrol system will relieve section foremen and other maintenance of way employees from necessary inspection under adverse weather or other conditions.

Many costly improvements have been built into the track structure in recent years that have made practical the consideration of changes in patrol methods. Maintenance officers approached by your committee have pointed out the following factors which contribute to a possible reduction in track patrol:

Rails have been made heavier and better. Larger ties have been installed, most of which are now treated. Practically all main line ties are protected with heavy tie plates. Rail anchors have been installed to keep rail from running. Heat-treated track fastenings and bolts are now used very largely. More and better ballast has been placed in most main line tracks. Cuts and fills have been widened, ditches and sub-drainage have been provided and many other improvements have been made. Automatic block signals and train control, safety switch locks and other electric safety devices give added protection to trains and decrease the necessity for frequent inspection. Rail-flaw detector cars, dragging-equipment and slide detectors have added immeasurably to the safety of train operation in a more effective manner than was possible by manual inspection.

While all of the above improvements have made possible on many railways, a reduction in the time spent by section forces in patrolling track, increased wheel loads and higher speeds of both passenger and freight trains, have made necessary higher standards of maintenance and closer attention to minor track defects.

On some of the heavy traffic roads, track was formerly patrolled by track walkers daily and in some cases continuously throughout the 24 hours. As early as 1914, roads having track walkers began discontinuing the practice of patrolling track in this manner

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    (b) Main lin
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    (d) Branch
    (e) Other tr
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15. Average miles
16. With improved
    as frequently

17. Is patrol study

DT = Double
(1) Track pat

TABLE 1—PART 1. TRACK PATROL METHODS USED BY PRINCIPAL RAILWAYS

Railroad No.	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10	No. 11
3. Date of adoption present method	No recent changes	No changes in 25 yrs.		1925	1934	1932-'33	----	----	----	1930	1936
4. Method of track patrol used											
(a) Main line auto. block	Section crew	Section crew		Foreman 2-3 men	Supervisor patrol	Special patrolmen	Section crew	Foreman 1-4 men	Section crew	Foreman 1 man	----
(b) Main line non-auto. block	do.	do.		do.	do.	do.	do.	do.	do.	do.	Patrolman
(c) Secondary lines	do.	do.		do.	do.	do.	do.	do.	do.	do.	Sec. crew
(d) Branch lines	do.	do.		do.	do.	do.	do.	do.	do.	do.	do.
(e) Other tracks	Laborer	----		do.	do.	do.	Laborer	Foreman	do.	do.	do.
5. No. of men used	Full crew	Full crew		do.	Supv. only	26% 1 man 74% 2 men	Foreman 2-3 men	Foreman 1-4	Full crew	Foreman 1 man	Foreman 2 men
6. Frequency of patrol				(1)							
Main line AB territory	Weekly	No regular interval	As necessary	Weekly	Daily	Daily	Weekly	Weekly	Daily	Each working day (2)	Work days
Main line non AB territory	do.	do.	do.	do.	do.	do.	As often as necessary	do.	do.	do.	do.
Secondary lines	do.	do.	do.	do.	do.	do.		do.	3 per week	do.	do.
Branch lines	do.	do.	do.	do.	do.	do.		do.	2-3 per week	do.	do.
Other tracks	do.	do.	Weekly	do.	----	do.		do.	As directed	do.	do.
7. Are track walkers used?	No	No	No	No	Emergency only	Yes—in yds. & heavy traffic main lines	In yards	No	No	No	No
8. Date track walkers discontinued	----	----	----	1925	1934		----	About 1919	----	----	----
9. Speed of motor car patrol, m. p. h.	Max. 15	Max. 15	----	Max. 20	Properly Insp.	8–12	----	----	8–20	10	15
10. On multiple track lines, do patrols run over all tracks?	----	No	----	Yes	Yes	Yes	----	----	Yes	Yes	----
11. Work done, if any	Defects corrected	None	Defects corrected	----	Very little	Emergency only	Defects corrected	----	Defects corrected	Everything	Everything
12. Length of time to patrol section	----	----	----	----	6 hrs.	8 hrs.	----	----	1 hr.	1.5–2 hrs.	1 hr.
14. Length of sections—miles											
Main lines	16	7.5 DT	8.7	9.0	22.0	----	----	8 DT 12 ST	8.0	5.5 DT 8 ST	15.0
Secondary lines	20	12–15 ST	10.4	15.0	----	----	----	14.	10.0	8.0	7.0
Branch lines	25 to 30	12–20 ST	19.2	20.0	----	----	----	16–24	13.0	8–14	----
15. Average miles assigned to special patrolmen	None	None	None	None	125	50	None	None	None	None	35
16. With improved track structure is it necessary to patrol as frequently?	No	No	----	No	No	----	----	No	Yes	Yes	No
17. Is patrol study worth the time and effort?	No	No	----	Yes	Yes	----	----	Yes	Yes	Yes	Yes

DT = Double Track, ST = Single Track.

(1) Track patrolled almost daily by supervisor and other maintenance of way employees on motor car. (2) Patrol three times per week where track conditions are good in automatic-block territory.

Railr

3. Date of adoption presen
4. Method of track patrol
   (a) Main line auto. blc

   (b) Main line non-aut
   (c) Secondary lines--

   (d) Branch lines-----
   (e) Other tracks-----
5. No. of men used-------

6. Frequency of patrol
   Main line AB territ
   Main line non AB
   Secondary lines---
   Branch lines------
   Other tracks------
7. Are track walkers used?.

8. Date track walkers disc
9. Speed of motor car patr
10. On multiple track lines,

11. Work done, if any-----

12. Length of time to patrol
14. Length of sections—mil
   Main lines--------
   Secondary lines---
   Branch lines------
15. Average miles assigned t
16. With improved track str
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17. Is patrol study worth th

DT = Double Track, S
(1) Foreman only on d
(4) Track walker used
(8) On main line non

Table 1—Part 2. Track Patrol Methods Used by Principal Railways

Railroad No.	No. 12	No. 13	No. 14	No. 15	No. 16	No. 17	No. 18	No. 19	No. 20	No. 21	No. 22
3. Date of adoption present method	1931	1939	1920	—	—	1931	1928	1924–1927	1936	1932	1933
4. Method of track patrol used (a) Main line auto. block	Foreman 1 man & spec.	Section crew	Section crew	Section crew	Section crew	Section crew (1)	Spec. motor patrol	Section crew	Tr. Insprs. & foreman	Sec. crew 25% Foreman (3) 75%	Sec. crew
(b) Main line non-auto. block	patrolman	do.	do.	do.	do.	do.	do.	do.	do.	Sec. crew 50% Foreman (2) 50%	do.
(c) Secondary lines											
(d) Branch lines	do.	do.	do.	do.	do.	do.	—	—	do.	—	Spec. patrol
(e) Other tracks	do.	do.	do.	do.	do.	do.	do.	do.	do. (3)	—	do.
5. No. of men used	Trk. walkers Foreman & 1 man spec. patrolman (5)	Walkers (4) 2–3	do. 2–6	Foreman 2	— Full force	do. 2–3	Foreman 2	Foreman 2–3	Foreman 1	Foreman 2 men (2)	— 3
6. Frequency of patrol											
Main line AB territory	Work days	Daily	Irregular (6)	1 3 per week	Work days	6 per wk.	Daily	3 per wk.	Daily	6 per wk.	6 per wk.
Main line non AB territory	do.	do.	do.	3 per wk.	do.	7 per wk.	—	do.	do.	2 per wk.	Daily
Secondary lines	do.	4–7 per wk.	do.	—	—	6 per wk.	—	—	do.	3 per wk.	6 per wk.
Branch lines	do.	2–4 per wk.	do.	1–3 wkly.	3 per wk.	1 per wk.	Daily	2 per wk.	do.	2 per wk.	do.
Other tracks	5-day wk.	1–7 per wk.	do.	1–6 per wk.	—	1–6 per wk.	No rule	—	Irregular	As req'd.	—
7. Are track walkers used?	Yes –where necessary	Yes (4)	No	Yes (4)	No	No	No	No	Yes-Spec. hazards	No	No
8. Date track walkers discontinued	—	1939	1920	—	—	1914	1928	1924–'27	—	1932	1933
9. Speed of motor car patrol, m. p. h.	6–10	12–15	10–15	8–10	20	15	20	10–15	10	10	10–15
10. On multiple track lines, do patrols run over all tracks?	Yes	No	No	—	Yes	Yes	Yes	Yes	Yes	Pass. trk. 1 day Frt. the next	No
11. Work done, if any	Everything	Everything	None	—	Defects corrected	Everything	Everything	Everything	Everything	Everything	Everything
12. Length of time to patrol section	1.5–4 hrs.	4-hrs.	2 hrs.	3-hrs.	40 min.	1–4 hrs.	8-hrs.	1 hr.	1.5–2 hrs.	6 hrs. (3)	1-hr.
14. Length of sections—miles	8.5 ST					4.5 DT				3-4 Tr.	
Main lines	4.5 DT	6.3	10	8–10	7	7 ST	10–12	7–8	10–17	6-D Tr.	7–8
Secondary lines	—	8.85	15	10	—	8–9	—	—	13–19	6-DT 10 ST	10
Branch lines	8–21	19.4	20	11–22	12-15	12	12–25	—	15–23	17	12
15. Average miles assigned to special patrolmen	35 DT	60 (7)	None	—	—	60 (8)	35–45 DT 45–90 ST	None	100	50	40–50
16. With improved track structure is it necessary to patrol as frequently?	No	Yes	No	No	—	—	Yes	No	Yes	Yes	No
17. Is patrol study worth the time and effort?	Yes	Yes	Yes	—	—	—	Yes	No	Yes	Yes	—

DT = Double Track, ST = Single Track.

(1) Foreman only on day men are off. (2) Qualified men on foot or motor car. (3) Some branch lines patrolled by foreman and one man.

(4) Track walker used in congested and terminal territory and other territory when section gangs are not working. (5) Sunday and holiday patrol discontinued. (6) Average twice weekly. (7) Used on only one branch.

(8) On main line non AB territory light motor cars with two men are gradually being established.

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3. Date of adoptio

4. Method of track
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(b) Main line
(c) Secondary
(d) Branch li
(e) Other tra
5. No. of men used
6. Frequency of pa
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7. Are track walke

8. Date track walk
9. Speed of motor
10. On multiple tra
11. Work done, if a

12. Length of time
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15. Average miles
16. With improved
as frequently

17. Is patrol study

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(1) Sunday ar
(3) Special pa
(6) Daily pat

TABLE 1—PART 3. TRACK PATROL METHODS USED BY PRINCIPAL RAILWAYS

Railroad No.	No. 23	No. 24	No. 25	No. 26	No. 27	No. 28	No. 29	No. 30	No. 31	No. 32
3. Date of adoption present method	1928	1937 (1)	No recent changes	No recent changes	Trk. supv.(2)	1931	1931	1930	1936	1938
4. Method of track patrol used	Sec. crew	Sec. crew(3)	Sec. crew	Sec. crew	Sec. crew	Supv. patrol	Supv. patrol	Signalmen	Sec. crew	Foreman or laborer
(a) Main line auto. block										
(b) Main line non-auto. block	do.	do.	do.	do.	do.	do.(4)	do.	None	Trk. supv.	do.
(c) Secondary lines	do.	do.	do.	do.	do.	do.	do.	Patrolman(6)	Sec. crew	do.
(d) Branch lines	do.	do.(3)	do.	do.	do.	do.	do.	Sec. crew	do.	do.
(e) Other tracks	do.	do.	Foreman	do.	do.	Foremen	Foremen	Foreman	Trk. walker	do.
5. No. of men used		2–3	2–4	1–4	1–3			2–5	Varies	1
6. Frequency of patrol					No regular interval(2)					
Main line AB territory	Irregular	3 per wk.	2-3 per wk.	Weekly		6 per wk.	Daily	Work days	Work days	Work days
Main line non AB territory	do.	do.	do.	do.	do.	Daily (4)	do.		do.	do.
Secondary lines	do	do.	do.	do.	do.	do.	do.	Daily	3 per wk.	do.
Branch lines	do.	Train days	2 per wk.	do.	do.			2 per wk.	2 per wk.	do.
Other tracks	do.		Weekly	do.	do.			Weekly	Irregular	do.
7. Are track walkers used?	No	No	Special hazards	(5)	No	No	No	No	Yards	No
8. Date track walkers discontinued	1928	Never used						1930		1938
9. Speed of motor car patrol, m. p. h.		Max. 20	15–20	Max. 20	Slow			10–20	8	Velocipede
10. On multiple track lines, do patrols run over all tracks?		Yes					Yes	Yes	No	No
11. Work done, if any		Everything	Everything	Everything		Emergency only	Emergency only	Everything	Defects corrected	Everything
12. Length of time to patrol section		1–1.5 hrs.	2–3 hrs.	8 hrs.	0.5 hrs.	8 hrs.	8 hrs.	6–8 hrs.	2	4
14. Length of section—miles					9–18 ST					
Main lines	8 DT	8	11–16	8.28	5–9 DT	5 DT		6 DT 11 ST	12	4 DT 8 ST
Secondary lines	12 DT	9–10		12.3	12–22			12	13	10
Branch lines	15 ST	12–16	17–20		15–25			12–20	21	12
15. Average miles assigned to special patrolmen		60–75	None	None	80–100	40–60	66	25–50	40–65	None
16. With improved track structure is it necessary to patrol as frequently?		No			Yes	No	No	No	Yes	No
17. Is patrol study worth the time and effort?	No	Yes				Yes	Yes	No	Yes	Yes

D.T. = Double Track, ST = Single Track.

(1) Sunday and holiday patrol discontinued. (2) Special patrol on light motor car used in three roadmasters' territories daily, all other patrol as often as required.

(3) Special patrol being tried on two AB districts and one branch. (4) Foremen patrol one day each week, Supervisor six days in non-AB territory. (5) Daily for five miles in terminal.

(6) Daily patrol by track patrolman on motor car where heavy traffic and rail conditions necessitate.

and today such track walkers are being used to only a limited extent by 10 of the 32 roads reporting. These roads use track walkers where hazardous conditions prevail; for patrolling yard tracks; and on main tracks in territory where motor-car patrols are impractical.

The fundamental patrol unit on practically all roads for years, has been the section crew. Starting in 1928 according to information obtained by the committee, one road established a special motor-car patrol and since that time other roads have either wholly or partially abandoned patrol by the full section crew and substituted special patrols of one or two men on light motor cars or velocipedes, two-man patrols being necessary where light motor cars are not available or where other conditions make it necessary to have more than one man inspecting track and doing other assigned work. Some roads use the "Track Supervisor" system described in detail in Appendix A, in which the supervisor does all the patrolling for several sections, as well as supervising the work of the section gangs. Other roads use track inspectors working over several sections, with little or no jurisdiction over the section gangs. On still others the section foreman or a qualified laborer inspects a single section or several sections or that portion of the section not covered by the section gang in going to and from work.

The committee finds from an analysis of the information obtained from the 32 reporting roads, that 11 railroads operating 61,100 miles of lines are now using one and two-man patrols to a considerable extent; and that seven additional railroads operating 25,900 miles of lines are using such patrol to a limited extent. Some of these latter roads are gradually changing over to the special patrol. At the present time, likewise, it has been found that 21 roads, comprising 102,700 miles of lines, patrol track wholly or in part by section gangs.

Frequency of Track Inspection

The table below summarizes the frequency of track inspection by the various railroads reporting:

Frequency of Inspection	*No. of Roads Reporting*	*Miles of Line Operated*	*Percent of Mileage*
Irregular and weekly	11	66,200	40.5
Three per week	4	15,900	9.7
Working days only	12	50,200	30.6
Daily	5	31,500	19.2
	32	163,800	100

Fifteen of the 32 roads reporting advise that owing to improved track conditions, the necessity for frequent track patrol is not as great as when the track structure was considerably weaker. Eight roads advise that, owing to increased wheel loads and higher speeds for both passenger and freight trains, frequency of track patrol is as necessary now as in the past. More than half of the railroads reporting indicate that a study of track patrol is worth the time and effort from standpoint of economical maintenance.

The problem of changing the method of track patrol depends upon a number of important factors, many of which vary between roads and between different sections of an individual road. Track and roadbed conditions, as well as the density and speed of traffic carried on the road or part of the road under study, must be given careful consideration. Any change in patrol methods likewise involves problems of personnel that are of paramount importance. Most railroads, when changing their patrol methods, have done so by establishing the new system on a portion of the line for trial and gradually extending the system when it was found applicable to other sections of the road.

The primary object in changing patrol methods is to increase the time of the section gangs on constructive maintenance work, as well as to secure more thorough track inspection.

Conclusions

1. A study of the methods and amount of necessary work that is accomplished by a track patrol is well worth the time and effort.

2. Large economies in labor have been effected by a reduction in track patrol made possible by improved track and roadbed conditions.

The report is presented as information.

Report of Committee 9—Highways

J. G. Brennan, *Chairman,*
F. D. Batchellor
H. A. Bertram
H. D. Blake
H. E. Brink
S. N. Crowe
A. T. Danver
A. R. Dewees
A. F. Dorley
W. M. Dunn
G. N. Edmondson
C. F. Edwards
P. W. Elmore
H. L. Englehardt
H. W. Fenno
P. M. Gault
*R. C. Gowdy
A. S. Haigh
J. P. Hallihan
H. A. Hampton
W. J. Hedley
Warren Henry
A. G. Holt
C. D. Horton
Maro Johnson
R. B. Kittredge
G. A. Knapp
A. E. Korsell
Fred Lavis
E. R. Lewis
E. E. Mayo
G. P. Palmer
Bernard Blum, *Vice-Chairman,*
W. C. Pinschmidt
T. M. Pittman
L. J. Riegler
Frank Ringer
H. M. Shepard
C. K. Smith
W. C. Swartout
C. A. Taylor
V. R. Walling
R. E. Warden
J. L. Way
J. W. Wheeler
W. L. Young

Committee.

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* Died. June 10, 1939.

To the American Railway Engineering Association:

Your committee respectfully reports on the following subjects:

1. Revision of Manual. Progress in study—no report.

2. Design and specifications for highway crossing at grade over railway tracks, both steam and electric, collaborating with Committee 1—Roadway and Ballast, and with American Society of Municipal Engineers and American Transit Association (Appendix A). Complete with recommended conclusions for publication in the Manual.

3. Comparative merits of various types of grade crossing protection, collaborating with Committee 10—Signals and Interlocking, Signal section and Safety section, AAR, and Highway Research Board. Progress in study—no report.

4. Develop drawings showing general requirements for installation of automatic gates. This subject was completed last year and the conclusions were adopted at the 1939 convention for publication in the Manual. The committee recommends that the subject be dropped.

5. Method of classifying grade crossings with respect to hazard (Appendix B). Progress Report.

6. Report requisites for flexible barrier type of grade crossing protection, collaborating with Signal section. Progress in study—no report.

7. Lamps on manual and automatic crossing gates, collaborating with Signal section (Appendix C). Complete with recommendation for publication in the Manual upon completion and adoption by Signal section of specifications for the design of lamp unit and the operating mechanism.

8. Striping of crossing gates (Appendix D). Recommended for adoption and publication in the Manual.

The Committee on Highways,
J. G. Brennan, *Chairman.*

Bulletin 414, December, 1939.

Roy C. Gowdy

The committee takes this opportunity to express the deep regret occasioned by the death on June 10 of one of its members, R. C. Gowdy, for many years the chief engineer of the Colorado & Southern, and a member of the AREA since 1909.

During the course of his 12 years of service on the committee, Mr. Gowdy gained the respect and admiration of its members, not only for his sound judgment, but also because of his earnest and conscientious approach to any assignment that was made to him.

His associates feel keenly the loss which the committee has suffered, and wish to record here their appreciation of his many admirable qualities.

Appendix A

(2) Design and Specifications for Highway Crossings at Grade Over Railway Tracks, Both Steam and Electric

Collaborating With Committee 1—Roadway and Ballast, and With American Society of Municipal Engineers and American Transit Association

W. J. Hedley (chairman, subcommittee), F. D. Batchellor, H. A. Bertram, H. D. Blake, S. N. Crowe, A. T. Danver, G. N. Edmondson, C. F. Edwards, P. W Elmore, H. W. Fenno, P. M. Gault, J. P. Hallihan, F. Lavis, H. M. Shepard, J. L. Way, W. L. Young.

The committee offers the following specifications covering monolithic concrete crossings for adoption and publication in the Manual:

SPECIFICATIONS FOR THE CONSTRUCTION OF MONOLITHIC CONCRETE CROSSINGS

1. General

These specifications cover the furnishing and placing of all materials necessary to the installation of a monolithic concrete crossing for highway with railroad track. This type crossing may be used for any paved highway. Its use is not recommended, however, for main line crossings or for crossings at any location where frequent track surfacing would be required. These specifications shall be carried out in detail and with first-class workmanship.

2. Track Structure and Size of Crossing

Track structure shall be designed and constructed in accordance with the standard AREA specifications, except that ballast shall be placed only to an elevation 6 inches below the bottom of the tie. Approaches to crossing shall be constructed in accordance with recommendations of the same standard specification. The length of the crossing, measured along the track, shall be sufficient to provide a paved roadway over the track at least as wide as the usable roadway immediately adjacent.

3. Track Support During Construction

The track shall be supported by means of brick, stone or metal blocking placed underneath the ties and the track brought to proper grade and alinement prior to pouring concrete.

4. Design of Crossing

The concrete shall completely encase the ties and shall extend 6 inches beyond the ends of the ties on each side. The bottom surface of the concrete shall rest on the ballast 6 inches below the bottom of the tie. The concrete shall be brought to a surface ¼-inch below the top of rail for the full width of the crossing, except that concrete shall be poured against pre-moulded, bituminous rail fillers or against removable wood or metal forms located on both sides of the rail.

Reinforcement of the crossing below the bottom of the tie shall consist of eight ¾-inch round bars, or equal, longitudinal the full length of the crossing; and ¾-inch round bars transverse with the crossing, spaced at 6-inch intervals through its length. These bars shall be supported on the ballast so that when the concrete is poured there is a minimum covering of 2½ inches.

Reinforcement of the concrete above the tie shall consist of eight ¾-inch round bars, running longitudinally for the full length of the crossing, these bars to be placed in pairs 3 inches apart, the center of each pair located one foot from the center of the rail. Bars shall be supported in a position half way between the top of the tie and the top surface of the finished crossing.

5. Rail Fillers

(a) Pre-moulded Bituminous Fillers

If pre-moulded bituminous fillers are used, they shall be placed on each side of the rail. These fillers shall be moulded to conform to the contour of the rail, and the one located on the gage side shall provide a flangeway 1¾ inches wide and 2 inches deep. The filler shall be 4 inches wide at its maximum dimension. The material of the filler shall conform to the following requirements:

(a) Asphalt	45 to 50 percent
(b) Mineral	35 to 45 percent
(c) Fiber	10 to 15 percent

Mineral shall consist of finely crushed slate, limestone, silica, or sand, or other similar mineral matter complying with the following gradation:

Passing No. 4 sieve	100 percent
Passing No. 10 sieve—not less than	90 percent

(b) Poured Bituminous Filler

If concrete is poured against removable wood or metal forms on each side of the rail, such forms shall be removed as soon as the concrete has set, and the space between the concrete and the rail filled with poured bituminous filler. On the outside of the rail, filler shall be poured flush with the top of the concrete. On the gage side, filler shall be poured to within 2 inches of the top of rail. Flangeway on the gage side shall be 2 inches wide.

Material used for poured bituminous filler shall be petroleum asphalt, free from water, and shall not foam when heated to a temperature of 392 degrees F. It shall conform to the following requirements:

(a) Flash point (Cleveland open cup), not less than	392° F.
(b) Softening point (ring and ball method), not less than	180° F.
(c) Penetration at 32° F., 200 g., 60 sec., not less than	15
(d) Penetration at 77° F., 100 g., 5 sec.	30 to 50
(e) Penetration at 115° F., 50 g., 5 sec., not more than	80
(f) Loss on heating at 325° F., 50 g., 5 hours, not more than	1.0%

(g) Penetration at 77° F., 100 g., 5 sec., of residue after heating at 325° F., as compared with penetration of asphalt before heating, not less than	60.0%
(h) Ductility at 77° F., not less than	3.0 cm.
(i) Bitumen soluble in carbon disulphide, not less than	99.0%
(j) Proportion of bitumen soluble in carbon tetrachloride, not less than	99.0%

The material shall be heated to a temperature between 300 degrees and 400 degrees F. with constant stirring to avoid local overheating, and at the time of pouring shall have a temperature of not less than 300 degrees F. Prior to pouring the filler, a layer of dry sand approximately ½ inch thick shall be placed and levelled over the bottom of the area to be filled. Care shall be taken to prevent foreign material from becoming mixed with the freshly poured filler.

6. End of Crossing

The end of the crossing shall be squared up with the track and shall be at the near face of a tie. It shall be beveled from the top surface of the concrete to the top of tie on a plane making an angle of 30 degrees with the horizontal.

7. Concrete

Concrete shall conform to AREA Specifications for Portland Cement Concrete, plain and reinforced, with a minimum compressive strength of 3,500 pounds per square inch in 28 days. High-early-strength cement is recommended. All concrete materials shall conform to requirements of American Railway Engineering Association specifications. Concrete shall be carefully placed under the ties and around the reinforcing so as to leave no voids in the finished slab. The top of the concrete shall be brought to a true surface and finished.

8. Steel

Steel for reinforcement shall conform to AREA Specifications for Billet Steel Concrete Reinforcement Bars. Bars shall be thoroughly cleaned and free from rust, and shall be carefully placed and effectively secured so that specified covering shall be provided.

9. Relation of Crossing to Adjacent Pavement

The elevation of the top surface of the crossing shall be the same as the highway pavement immediately adjacent to the crossing. A ½-inch expansion joint shall be provided between the concrete crossing and the pavement.

Appendix B

(5) Methods of Classifying Grade Crossings With Respect to Hazard

E. R. Lewis (chairman, subcommittee), F. D. Batchellor, H. A. Bertram, H. D. Blake, A. T. Danver, W. M. Dunn, W. J. Hedley, C. D. Horton, A. E. Korsell, F. Lavis, W. C. Pinschmidt, T. M. Pittman, L. J. Riegler, Frank Ringer, V. R. Walling, J. W. Wheeler.

The work of your subcommittee this year consisted of a review of the 1938 report and a canvass of existing methods of classifying grade crossings as to hazard and other pertinent information, together with studies of these methods. As a review of the report appearing in Bulletin 407, December, 1938, and in the Proceedings for 1939, Vol. 40, indicated the need for correction and revision of item 2. Factors, this matter is presented below as revised:

Factors

The chief factors of danger comprise, (A) the physical characteristics of the crossing, which factors are classed as constants, and (B) the railway and highway traffic passing over the crossing, which factors are classed as variables, as shown in the following tables. These factors should be given consideration in conjunction with the accident record of the crossing.

Table A

Physical Characteristics

1. Angles
    - a. Intersection
    - b. View
2. Highway
    - a. Alinement
    - b. Grades
    - c. Traffic lanes
    - d. Roadway surface
3. Railway
    - a. Alinement
    - b. Grades
    - c. Tracks
4. Obstructions to View
    - a. Total
    - b. Partial
    - c. Fixed
    - d. Seasonal
5. Environment
    - a. Isolated highways
    - b. Intersecting streets
    - c. Side drives
    - d. Nearby, non-intersecting roads and drives

Table B

Traffic Conditions

1. Railway Traffic
    - a. Volume
    - b. Speed
    - c. Character
    - d. Standing cars
2. Highway Traffic
    - a. Volume
    - b. Speed
    - c. Character
    - d. Standing vehicles

*3. Opposing Traffic, Peak Periods
    - a. Day
    - b. Night
    - c. Seasonal
    - d. Special

4. Pedestrian Traffic, Peak Periods
    - a. Day
    - b. Night
    - c. Special
5. Influences of Natural Phenomena
    - a. Frost
    - b. Snow, ice
    - c. Fog, darkness
    - d. Sun glare
    - e. Storms

Attention is invited to the last sentence under Factors preceding the tables, which reads—"These factors should be given consideration in conjunction with the accident record of the crossing."

The five-year accident records on one railroad indicate that the number of grade crossings on which any accident reportable to the Interstate Commerce Commission occurred, does not greatly exceed one crossing in ten.

A search of grade crossing accident evidence indicates that few such accidents can be allocated to any but the personal element. In most cases the driver is at fault. In a few cases, crossing characteristics are contributory causes, with weather conditions prominent in the list.

In many cases the primary cause of the accident is unrevealed in eye witness evidence, but the railroad claim agent's files usually bring it to light. It is suggested that consideration of accidents be based on evidence obtained from claim agent's files, and

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* Opposing—Involved in crossing delays.

that suitable weighting therefor be added to the factor or factors of Tables A and B which are involved.

Your subcommittee recommends deleting topic 6—Climatic Conditions, from Table A—Physical Characteristics, and replacing it as topic 5 in Table B—Traffic Conditions, as shown above. While it is true that Climatic Conditions are physical characteristics, it is not the weather but the resulting driving conditions that we are to enumerate, such as lack of traction due to snow, reduced visibility due to fog, etc.

Studies of the several methods submitted to your subcommittee and replies from representatives of 30 state highway departments, point to two lines of thought—(1) Empirical Formulas, including physical elements and traffic elements and (2) Methods based on traffic alone. Since the only constants involved are among the physical characteristics and traffic is one of the most important variables, (1) Empirical Formulas are favored. The proposed use of the method influences selection.

(2) On the other hand it is the sense of your subcommittee that the traffic factor deserves at least an equal weighting with other most weighted factors and suggests that due stress must be given to the assumption that the method will be used to compare series of a few hundreds of crossings rather than thousands and that while commonly a preponderance of the crossings are sparsely traveled, the tables should be applicable to city street crossings having 10,000 or more daily highway movements. Likewise, only opposing traffic is of importance.

This is submitted as a progress report.

Appendix C

(7) Lamps on Manual and Automatic Crossing Gates, Collaborating With Signal Section

W. L. Young (chairman, subcommittee), H. D. Blake, A. F. Dorley, C. F. Edwards, P. W. Elmore, H. L. Engelhardt, A. S. Haigh, H. A. Hampton, A. G. Holt, C. D. Horton, G. A. Knapp, E. E. Mayo, T. M. Pittman, J. L. Way.

Your committee offers the following recommended practice with respect to lamps on manual and automatic gates, for adoption and publication in the Manual, upon the completion and adoption by the Signal section of specifications for the design of the lamp unit and the operating mechanism.

LAMPS ON MANUAL AND AUTOMATIC GATES

Manually Operated Crossing Gates

1. On manually operated crossing gates one or more lamps shall be provided on each gate arm, facing the highway for night indication only, so arranged, as far as practicable, as not to be visible from the track.

2. Oil lamps, when used, shall be in accordance with Signal Section, AAR drawings 1497, 1498 and 1499.

3. Electric lighting may be provided for manually operated crossing gates where reliable a. c. power is available at the crossing.

4. Electric lamps, when used, shall be arranged to light when the gate arm starts to lower and remain lighted until the gate arm returns to the open position.

5. Electric lamps and operating mechanism shall be in accordance with specifications prepared by the Signal section.

Automatic Crossing Gates

6. Automatic crossing gate arms extending over the roadway shall be equipped with three red electric lamps for each gate arm.

7. The lamps shall shine in both directions along the highway for night indication only.

8. The light nearest the tip of each arm shall burn steadily and the other two lights on each arm shall flash alternately.

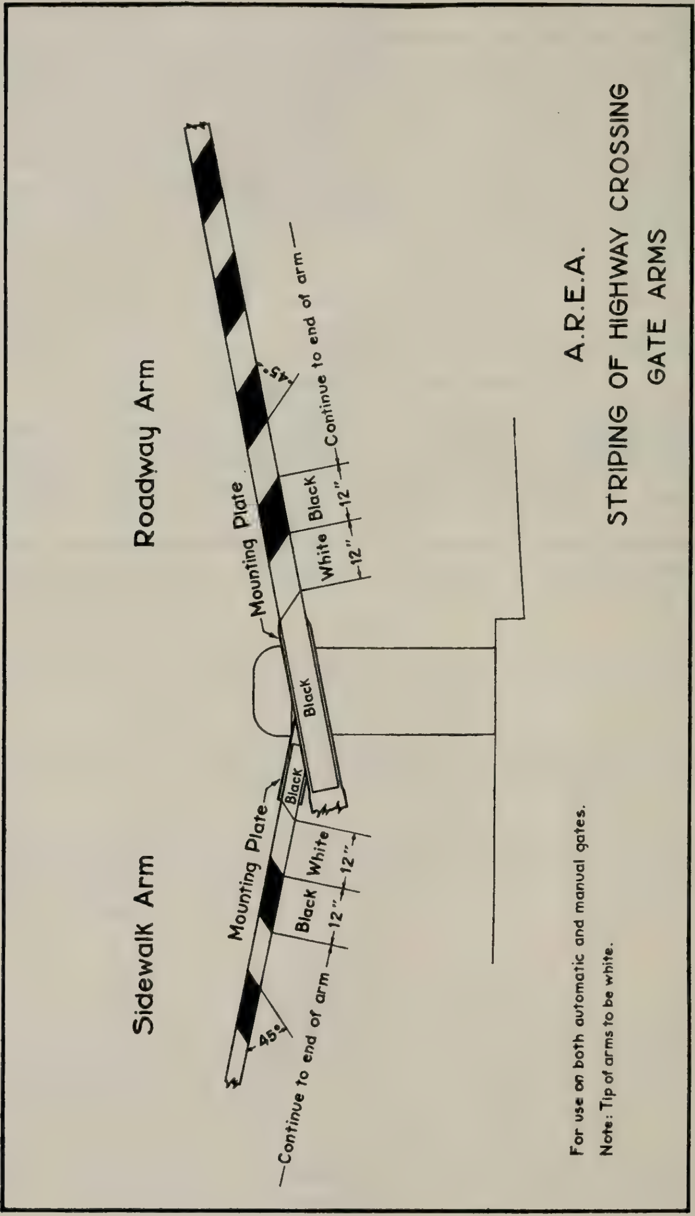
9. The design of the lamp unit and the operating mechanism shall be in accordance with specifications prepared by the Signal section.

Appendix D

(8) Striping of Crossing Gates

G. P. Palmer (chairman, subcommittee), F. D. Batchellor, A. R. Dewees, W. M. Dunn, G. N. Edmondson, H. L. Englehardt, J. P. Hallihan, W. J. Hedley, A. G. Holt, Maro Johnson, R. B. Kittredge, A. E. Korsell, E. R. Lewis, T. M. Pittman, Frank Ringer, C. K. Smith, C. A. Taylor, R. E. Warden, J. L. Way and W. L. Young.

The committee submits a drawing showing Striping of Highway Crossing Gate Arms for use on both automatic and manually operated gates for adoption and publication in the Manual as recommended practice.



A.R.E.A.
STRIPING OF HIGHWAY CROSSING
GATE ARMS

For use on both automatic and manual gates.

Note: Tip of arms to be white.

Striping of Highway Crossing Gate Arms

Report of Special Committee on Clearances

A. R. Wilson, *Chairman,*	J. G. Brennan	J. F. Leonard
John E. Armstrong	H. M. Church	H. G. Morgan
Hadley Baldwin	B. W. DeGeer	D. B. Thompson
A. E. Botts	L. H. Laffoley	R. A. Van Ness

Committee.

To the American Railway Engineering Association:

Your committee respectfully submits the following report on the assignments:

1. Revision of Manual—Fig. 1.

2. Clearances as affected by half-through inter-track girders and structures, third rail, signal and train control equipment, collaborating with Electrical section and with Mechanical and Operating divisions. Progress in study—no report.

3. Provide clearance diagrams for recommended practice, collaborating with committees concerned—Fig. 1-a.

Assignments 1 and 3 are covered by diagrams 1 and 1-a, with the recommendation that they be adopted and printed in the Manual as recommended practice.

The Special Committee on Clearances,
A. R. Wilson, *Chairman.*

Bulletin 414, December, 1939.

CLEARANCE DIAGRAM FOR RAILWAY BRIDGES

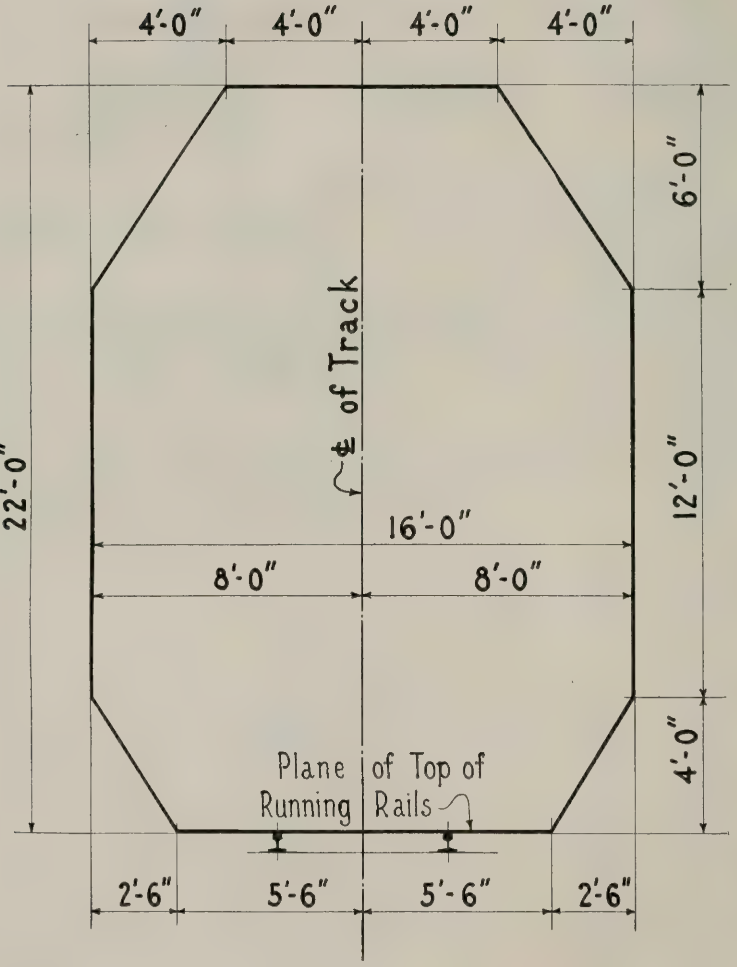


FIGURE 1

NOTE:

For Permissible Encroachment of girders projecting above the Top of Rail see FIGURE 1a.

CLEARANCE DIAGRAM
FOR
RAILWAY BRIDGES

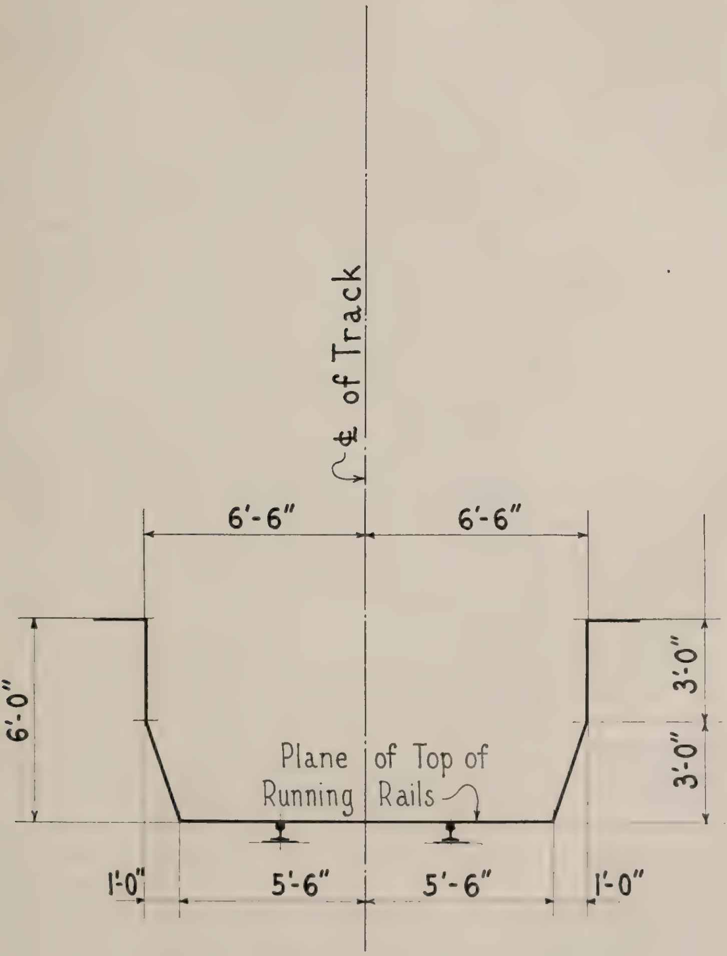


FIGURE 1a

Clearance Diagram for girders projecting above the Top of Rail.

Report of Committee 7—Wood Bridges and Trestles

H. M. Church, *Chairman*,
H. Austill
M. W. Beach
W. J. Bennett
G. M. Cornell
F. H. Cramer
G. S. Crites
S. F. Grear
W. E. Hawley
H. C. Heinlen
C. J. Hogue
C. S. Johnson
J. V. Johnston
W. D. Keeney
J. E. Myer
W. O. Nelson
J. A. Newlin
W. H. O'Brien
W. A. Oliver
R. P. Hart, *Vice-Chairman*,
W. L. Peoples
G. W. Rear
Arthur Ridgway
W. R. Roof
W. J. Ryan
W. C. Schakel
L. W. Smith
T. G. Sughrue
Committee.

To the American Railway Engineering Association:

Your committee respectfully reports on the following subjects:

1. Revision of Manual. Progress in study—no report.

2. Simplification of grading rules and classification of timber for railway uses, collaborating with other organizations interested (Appendix A). Presented as information.

3. Overhead wood or combination wood and metal highway bridges, collaborating with Committee 15—Iron and Steel Structures. Progress in study—no report.

4. Specifications for design of wood bridges and trestles. Progress in study—no report.

5. Bearing power of wood piles, with recommendation as to methods of determination, collaborating with Committee 8—Masonry. Progress in study—no report.

6. Recommended relationships between the energy of hammer and the weight or mass of pile for proper pile driving, to include concrete piles, collaborating with Committee 8—Masonry. Progress report presented as information. Specifications for Driving Wood Piles (Appendix B). Recommended for inclusion in the Manual, to supersede pages 7–51 and 7–52.

7. Design of timber structures

    (a) To give longer life with lower cost of maintenance.
    (b) For heavy loading. Progress in study—no report.

8. Review specifications for overhead highway bridges of the American Association of State Highway Officials in so far as they relate to wood construction, conferring with that association and Committee 15—Iron and Steel Structures. Progress in study—no report.

9. Fireproofing wood bridges and trestles, including placing of fire stops. Progress in study—no report.

10. Specifications and design of fastenings for timber structures, including metal joint connectors (Appendix C). Progress report submitted as information.

11. Use of tar and asphalt compositions for wearing surfaces on wood floored highway bridges (Appendix D). Recommended for publication in the Manual.

The Committee on Wood Bridges and Trestles,
H. M. Church, *Chairman*.

Bulletin 415, January, 1940.

Appendix A

(2) Simplification of Grading Rules and Classification of Timber for Railway Uses, Collaborating with Other Organizations Interested

H. Austill (chairman, subcommittee), M. W. Beach, W. E. Hawley, C. J. Hogue, C. S. Johnson, J. A. Newlin, W. H. O'Brien, L. W. Smith.

The regulations governing the size of a knot permitted in any timber and its influence on strength are based on the following definition of a knot: "That portion of a branch which has become incorporated in the body of a tree." Even to one familiar with timber it is often hard to distinguish between a knot and the surrounding wood. This is especially true if he has not made a study of how the wood is formed in and around the knots.

For this reason your committee offers as information the following memorandum prepared by one of its members which was previously published in the report of ASTM Committee D–7 for 1939. It is believed that the general observations offered will aid the inspector in solving the often vexing problem of what the limits of a knot are.

The Size of a Knot

By John A. Newlin*

The ASTM standards for timber give very definite knot sizes that are to be permitted in any given grade and size of timber and a very concise and accurate definition of a knot. But it is not always easy to trace the outline of the knot on the surface of a timber and segregate the knot from the cross grain around the knot, which is a part of the body of the tree.

Sometimes there is a difference in color between the end grain of the limb wood and the surrounding wood. Sometimes there is a marked change in color that merely marks the heartwood of a live knot, and the sapwood of the knot may have the same color as the surrounding wood.

Again, we find knots in which there is practically no difference in color. The body of the tree is usually enlarged at a knot so that, when a knot is sawed through, the ring growth of the body wood looks very much like a part of the knot. How then are knot sizes to be determined?

There are two ways of determining the limits of a live knot when color or general appearance does not clearly demonstrate the boundary of the knot:

First.—The rings on the top of a limb are usually narrower than those on the bottom; and on a tangentially cut surface these rings at the top are narrower than those showing immediately above the knot in the body of the tree; also the rings in the body of the tree get wider as you measure away from the knot. The growth ring at the top of the knot can be traced around the knot to outline the size of the knot. When the knot is cut at an angle there will, as a rule, still be a place to one side of the top where the relatively narrow ring growth of the knot is suddenly changed to the wider growth rings of the tree trunk (see A, Fig. 1). On the side of the knot opposite these narrow growth rings, the growth rings will usually be found to get wider all the way from the pith center out and it is often very difficult to establish the limit of the knots on that side except by tracing the growth rings from the other side of the knot.

Second.—Checks on the face of a knot run radially from the pith center and those running to the sides never run beyond the knot without an abrupt change in direction.

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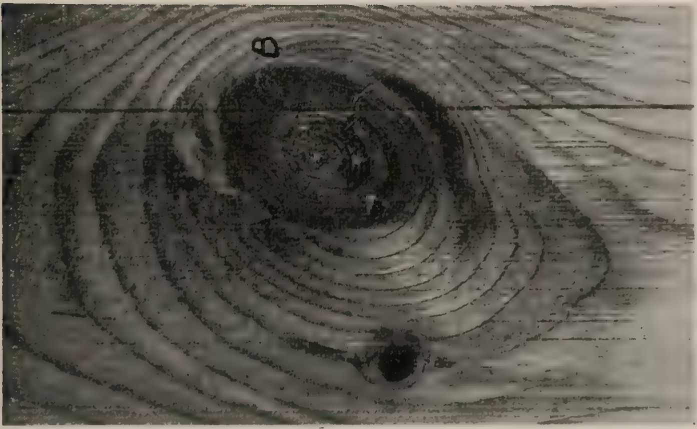


FIG. 1.

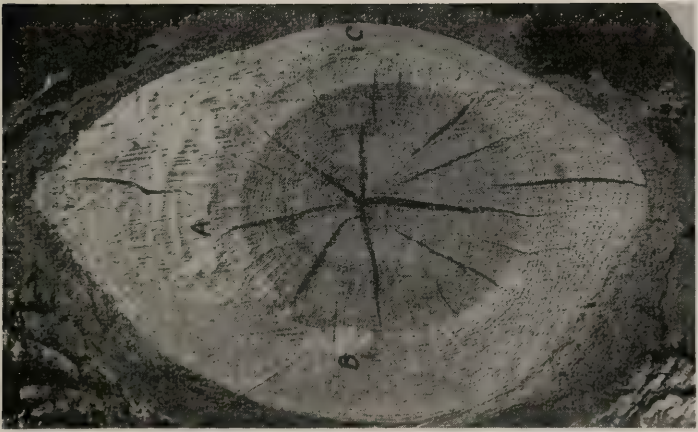


FIG. 2.

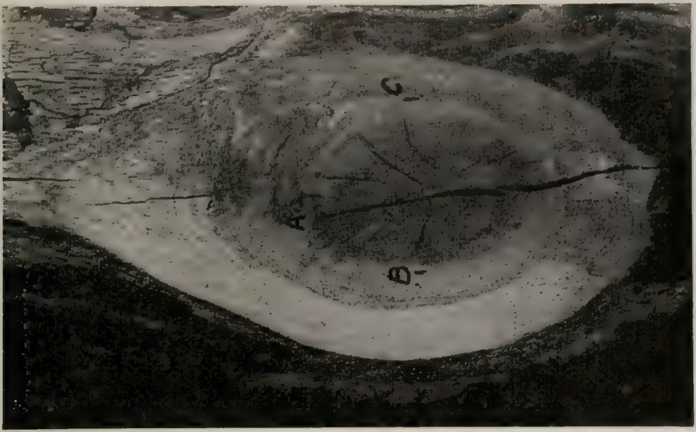


FIG. 3.

To one trying to determine the size of a knot, the oaks give a great deal of trouble due to two principal causes: First, color cannot be depended upon to outline the knot, and second, the body of the oak tree is usually greatly enlarged at a limb and a large amount of irregular or burly growth is introduced by a cut through the knot.

On the top of the oak knot it will usually be found that the very definite growth rings of the knot change very abruptly to burly irregular grain (see A, Fig. 2), often with bark pockets (see A, Fig. 3). This is the body wood above the knot. The radial checking in the oak knot is often very prominent and can be used to determine the limits of the knot. The checks follow the rays and run approximately radially from the pith center of the knots. The checks running to the bottom of the knot may run approximately straight far beyond the limit of the knot and occasionally those running to the top may run through the burly wood above the knot in more or less of a straight line, but the checks running to the sides of the knot, while they may stop short of the limit of the knot, never run without an abrupt change of direction beyond the limit of the knot (see B, Fig. 1 and 2).

Appendix B

(6) Recommended Relationships Between the Energy of Hammer and the Weight or Mass of Pile for Proper Driving

To Include Concrete Piles, Collaborating with Committee 8—Masonry, and Prepare Specifications for Pile Driving

H. C. Heinlen (chairman, subcommittee), G. S. Crites, R. P. Hart, W. D. Keeney, W. L. Peoples, W. J. Ryan, T. G. Sughrue.

The specifications for driving wood piles which follow, are recommended for inclusion in the Manual, to supersede the matter on pages 7–51 and 7–52.

SPECIFICATIONS FOR DRIVING WOOD PILES

1. Scope

These specifications cover the driving of wood piles in trestles, foundations, and for protection work. For the driving of concrete piles and steel piles, see the "Masonry" chapter.

2. Tests

A thorough exploration shall be made at the proposed site by borings or preliminary test piles as indicated in the "Design of Pile Trestles" in this chapter and in the "Specifications for Pile Foundations" in the "Masonry" chapter.

3. Materials

The kinds of wood, physical requirements, dimensions, and manufacture are specified in this chapter.

4. Handling of Material

Treated piles shall be handled with rope slings, taking care to avoid dropping, bruising or breaking of outer fibers, or penetrating the surface with tools. Sharp pointed tools shall not be used in handling treated piles or turning them in the leads.

The surface of treated piles below cut-off elevation shall not be disturbed by boring holes or driving nails or spikes into them to support temporary material or staging.

Staging may be supported in rope slings carried over the tops of piles or attached to pile clamps of an approved design.

5. Selection and Preparation of Piles

(a) Size

The piles in each bent of a pile trestle shall be selected for uniformity of size to facilitate placing of the brace timbers.

(b) Pointing

Piles may be pointed where soil conditions make it desirable.

(c) Pile Shoes

Where the driving of a test pile or former experience at the site indicates that difficult driving will be encountered, metal shoes of an approved design may be attached to the tips of the piles.

(d) Collars

Where the heads of the piles tend to check or split under the hammer, the heads shall be wrapped with wire, or metal bands applied to obviate this condition.

(e) Driving Cap

The heads of all piles shall be protected, while being driven, with a cushion cap of approved design. Care shall be exercised to insure full bearing of the driving cap on the pile for proper distribution of the hammer blow.

6. Types of Hammers

Pile driving shall not be started on any project until approval is secured from the Engineer as to the type and weight of the hammer to be used.

Piles shall be driven with the heaviest hammer that, in the judgment of the Engineer, can be used to secure maximum penetration without appreciable damage to the pile.

Where a drop hammer is used, the striking ram shall weigh not less than 3,000 pounds. The fall shall be so regulated as to avoid injury to the pile.

A steam hammer shall be used where the shock to surrounding material may cause damage to an adjacent structure.

7. Driving

(a) Leads

Pile driver leads shall be constructed in such a manner as to afford freedom of movement of the hammer, and they shall be held in position by guys or stiff braces to insure support for the pile during driving.

(b) Followers

The use of followers shall be avoided if practicable and shall be used only with the written permission of the Engineer.

(c) Line

Piles shall be driven as accurately as possible in the correct location, true to line both laterally and longitudinally, and to the vertical or batter lines as indicated on the plans. On sloping ground or under difficult conditions of driving, the pile shall be started in a hole or guiding templet or other necessary means provided to insure driving in the proper location. In case a pile works out of line in driving, it shall be properly alined before it is cut off or braced, and the distance that it may be pulled shall be determined by the Engineer.

(d) Jetting

When water jets are used, the number of jets and the volume and pressure of water shall be sufficient to freely erode the material adjacent to the pile. The plant shall have sufficient capacity to deliver at least 100 pounds per square inch pressure at two ¾-inch nozzles. Before the desired penetration is reached, the jets shall be removed and the pile finally set under normal driving by at least 50 blows from a gravity or single-acting steam hammer or 200 blows from a double-acting steam hammer.

(e) Drilling

When it has been satisfactorily demonstrated to the Engineer that piling cannot be driven in the regular manner or by jetting, holes may be drilled to facilitate the driving.

Where drilling is permitted, the holes drilled shall have a diameter not more than one inch larger than the tip diameter of the pile and the drilling will continue only through the strata of hard material obstructing the driving. Where the hard material extends below the desired penetration, the drilling shall be stopped above that penetration level and the pile finally set under normal driving by at least 50 blows from a gravity or single-acting steam hammer or 200 blows from a double-acting steam hammer.

(f) Drilling and Shooting

Where it is impossible to drive, jet, or drill and drive the piles, the Engineer will determine whether shooting the holes with explosives or redesign of the structure is necessary. Shooting will not be permitted except by written permission of the Engineer.

(g) Penetration

It is expected that piles shall be driven, jetted, or drilled and driven to the full penetration shown on the plans or as otherwise required. This shall not be construed to mean that driving may stop when such penetration as shown on the plans has been secured, but on the contrary, driving shall continue in every case until the total penetration obtained is satisfactory to the Engineer, regardless of the fact that sufficient bearing capacity as determined by formula may be obtained at a lesser depth.

(h) Bearing Capacity

Where possible, test piles shall be driven and loading tests made before construction is started. However, if these test data are not available, the following "Engineering News" formulas may be used to determine the approximate bearing capacity of piles:

For drop hammers $P = \frac{FWh}{S+1}$.

For single-acting steam hammers $P = \frac{FWh}{S+0.1}$.

For double-acting steam hammers $P = \frac{Fh\,(W + ap)}{S + 0.1}$.

Where P = safe load in pounds.
W = weight of hammer or ram in pounds.
h = fall of hammer or stroke of piston in feet.
S = average penetration in inches per blow, for the last 5 blows of a drop hammer or 20 blows of a steam hammer.
a = effective area of piston in square inches.
p = mean effective steam pressure in pounds per square inch.
F = 2 for piles driven to practical refusal in any material.

These formulas are applicable only when the hammer has a free fall, the head of the pile is not broomed or crushed, the penetration is reasonably uniform, and there is no appreciable bounce of the hammer. The character of the soil penetrated; conditions of driving; spacing, size and length of piles; and experience under similar conditions; shall be given due consideration in determining the value of piles by formula.

For jetted piles, the same formulas will apply and the test shall be made when driving is resumed after removal of the jets. For piles driven in drilled holes, the tests shall be made after the tip of the pile has passed the bottom of the hole.

(i) Delay

When driving is interrupted before final penetration is reached, record for bearing capacity shall not be taken until at least 12 inches penetration or refusal has been obtained after driving has been resumed.

(j) Overdriving

When the point of refusal is reached, care shall be taken to avoid damaging the pile by overdriving. This condition is indicated when the hammer begins to bounce, or when the energy of the blow is dissipated in the bending or kicking of the pile.

(k) Replacing

Any pile driven too far out of line, driven below cut-off elevation, or so injured in driving or straightening as to impair its structural value as a pile under the conditions of use, shall be pulled and replaced by a new pile.

8. Framing

(a) Cut-off

The tops of piles shall be pulled into line if necessary, fixed in position, cut off to a true plane as shown on the plans, and at the elevation established by the Engineer. Piles shall show a solid head at the plane of the cut-off.

(b) Treatment

After the cut-off has been made, the tops of treated piles shall be saturated with hot preservative, followed by two coats of hot sealing compound. The sealing compound shall be an asphaltum or a mixture of creosote and roofing pitch, mixed to about the consistency of vaseline, and brushed thoroughly into the wood. For detailed description of kinds of preservatives, methods of application, and handling of treated piles and timber, see Section V of Chapter 17—Wood Preservation.

(c) Pile Covering

Where the plans call for a heavy roofing material or galvanized metal pile covering, it shall be placed on the tops of the piles immediately after treatment, the edges bent down over the sides of the pile, neatly trimmed, and fastened with roofing nails.

(d) Placing Caps

Caps shall be placed while the piles are held in correct position. Where drift bolts are used for making the connection, the caps and tops of piles shall be bored the same diameter as the drift bolt and to a depth of 3 inches less than its length. Where the connection is made with straps and bolts, see paragraph *(f)* for boring and treatment of holes.

(e) Bracing

Piling shall not be trimmed or cut to facilitate the framing of sway or longitudinal bracing. Where necessary, filler blocks shall be used between the pile and brace to establish the bracing in a true plane.

(f) Holes for Bolts

Holes shall be bored the same diameter as the bolt.

When holes are bored in treated piles, caps or bracing in the field, the entire hole shall be pressure treated or swabbed with hot preservative and sealing compound just before the bolt is placed. Bolts shall be cleaned of rust and scale, and dipped in hot sealing compound before placing. All unused holes shall be plugged at each end with tight fitting treated wooden plugs.

(g) General Field Treatment

Where it is necessary to disturb the surface of treated piles or timber, or where the surface has been damaged in handling, such surfaces shall be treated with a liberal quantity of hot preservative followed by two applications of hot sealing compound.

9. Foundation Piles

For the design of pile foundations, exploration at the site, and test pile loading, see the "Masonry" chapter.

The general specifications above shall apply to the driving of wood foundation piles.

Pile driving shall not be started until foundation excavation has been carried to plan depth.

After all of the piles are driven, tests shall be made to determine if any of the piles have raised due to driving of adjacent piles. Any piles that have raised shall be driven down again.

After driving is completed, the piles shall be cut off as shown on the plans and at the elevation established by the Engineer. All loose and displaced materials down to the level of original excavation shall be removed from the foundation pit, leaving a clean solid surface on the piles, and bottom and walls of the pit.

10. Protection Work

The general specifications above shall apply to the driving of wood piles for protection work.

It is essential that protection work be constructed as securely as possible, accurately located as shown on the plans, and the piles driven to a fixed penetration or to refusal as may be determined by the Engineer.

Recommended Relationships Between the Energy of Hammer and Weight or Mass of Pile for Proper Driving

Your committee offers as information the following redraft of the conclusions presented in its report for 1939. The revision has been confined to the first paragraph under "Steam Hammers".

In determining the weight or size and capacity of the hammer to be used for any service, due consideration must be given to the weight and spacing of the piles, the character and condition of the soil to be penetrated, conditions of driving, and former experience at the site or under similar conditions. The blow should be struck by a ram having sufficient energy to overcome the inertia of the pile and the frictional and elastic resistance encountered, and having sufficient weight to reduce to a minimum the portion of this energy which is unavoidably dissipated in destructive work during impact. As a general rule, piles should be driven with the heaviest hammer that, in the judgment of the Engineer, can be used to secure maximum penetration without appreciable damage to the pile.

Steam Hammers

For driving concrete piles, the striking part of the hammer should weigh not less than 2,500 pounds and develop energy per blow of 8,750 foot pounds per cubic yard of concrete contained in the pile to be driven.

For driving wood piles, the weight of the striking part of the hammer should be not less than the weight of the pile to be driven.

In general, the minimum weight of the entire hammer and of the striking part, and the length of stroke should, where practicable, be specified for each project. Where hard driving is encountered, it may be necessary to reduce the length of stroke in order to avoid injury to the pile.

Gravity Hammers

For driving either concrete or wood piles, the weight of the striking ram shall be not less than 3,000 pounds and the drop shall be so regulated as to obtain the desired penetration without appreciable injury to the pile.

Appendix C

(10) Specifications and Design of Fastenings for Timber Structures, Including Metal Joint Connectors

Subcommittee—G. M. Cornell, G. S. Crites, R. P. Hart, H. C. Heinlen, W. R. Roof, W. J. Ryan, L. W. Smith.

Developments in Modern Timber Connectors for Railway Structures

Since the report of Subcommittee 8 on Design of and specifications for washers, separators, cap stringer straps and other wood bridge and trestle fastenings, of Committee 7 in 1936, four new types of timber connectors have been developed, two of these should be of particular interest to members of the AREA and the two others are more or less of interest to engineers in general.

Spike-Grid

Without doubt the most important type of connector for timber trestle construction is the spike-grid. These are manufactured of malleable cast iron and are made in three styles: The flat grid, for installation between two sawn timber faces; the single-curve grid, for installation between a pile and a sawn timber; and the double-curve grid, for installation between two piles or poles. The single-curve and flat grids are used to excellent advantage in attaching trestle bracing to rectangular posts or piles and to caps. With these connectors it is possible to develop a much larger portion of the inherent strength of the braces than is practical by other methods, and the stiffness of the joints is greatly increased.

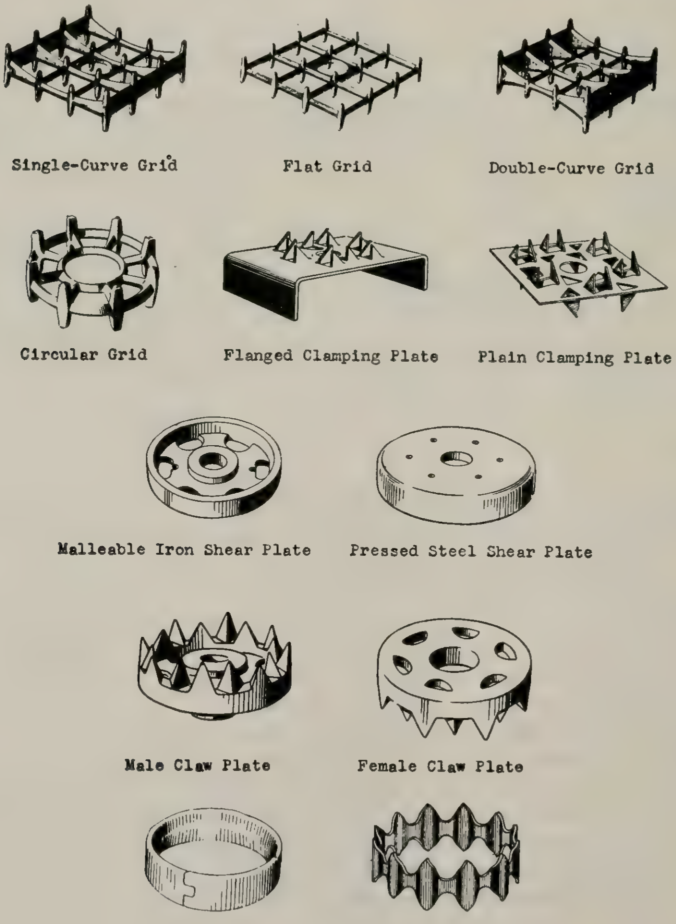
Spike-grids require no pre-grooving for their installation but are simply placed between the two members to be fastened and then forced into the wood by pressure developed by turning up a nut on a high-strength steel bolt. After the grid is seated this high strength bolt is replaced by a standard machine bolt to complete the installation.

It has been found that when installed in properly pressure-treated material that the teeth of the grids penetrate only a small fraction of the depth of treatment. Also, the pressure exerted on the wood by the teeth as they are inserted causes the treating fluid to flow around the teeth and completely fill any small checks which may develop.

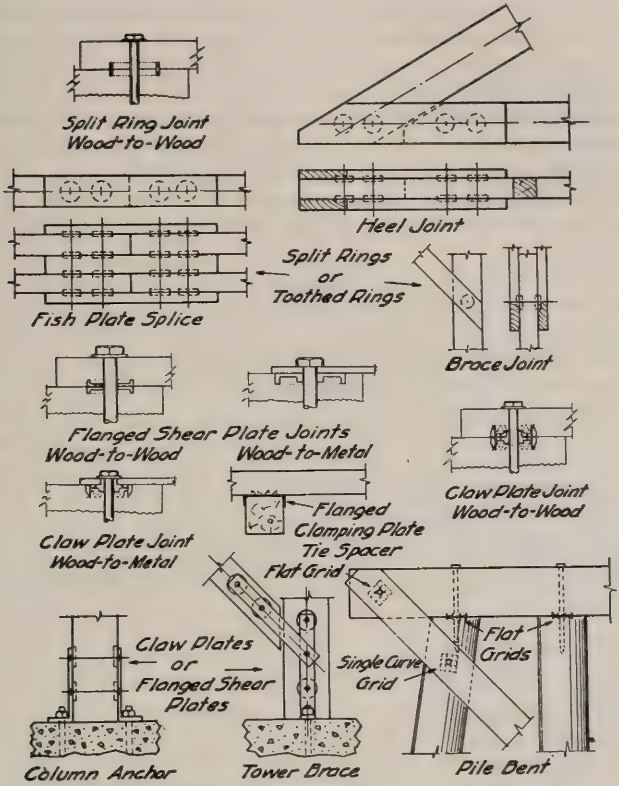
The single-curve grid is the first timber connector that has been developed which lends itself to the joining of a flat sawn face to the curve of a pile without dapping or any other scarfing operations, and was designed especially for this one purpose.

The allowable design loads in pounds for spike-grids, based on a factor of safety of four on ultimate test loads when used in dense grades of Douglas fir and southern pine, are as follows:

Type of Grid	*Size Inches*	*Bolt Diam. Inches*	*Load Parallel to Grain*	*Load Perpendicular to Grain*
Square				
Flat	4⅛ × 4⅛			
Single Curve		¾	4,100	3,300
Double Curve		1	4,500	3,600
Round				
Flat	3¼	¾	3,700	3,000


Single-Curve Grid
Flat Grid
Double-Curve Grid
Circular Grid
Flanged Clamping Plate
Plain Clamping Plate
Malleable Iron Shear Plate
Pressed Steel Shear Plate
Male Claw Plate
Female Claw Plate
Split Ring
Toothed Ring

Types of Connectors Discussed in This and Previous Reports of the Committee.



Suggested Applications of Connectors.

Claw Plates

Claw plates are malleable castings consisting of a circular plate with teeth arranged about the perimeter of one face and with or without a cylindrical hub on the opposite face, concentric to the central bolt hole. The hubbed design is intended primarily for steel-to-wood connections, but by using the hubbed plate and one without a hub they may be placed back to back to make a wood-to-wood joint. These connectors are made in three sizes, namely: 2⅝ in., 3⅛ in., and 4 in. Their chief use is in footing connections and in connections to metal gusset plates. The hub adds considerably to the shear value of the connection and the connection develops unusually large loads for the size of the bolt used to hold the joint together.

The allowable design loads in pounds for claw plates on ultimate test loads when used in dense Douglas fir and southern pine, and based on a safety factor of four, are as follows:

Size of Claw Plate Inches	*Bolt Diam. Inches*	*Load Parallel to Grain*	*Load Perpendicular to Grain*
2⅝	½	3,600	2,720
3⅛	½	4,700	3,560
4	¾	5,980	4,570

For loads at various angles to the grain, a straight line reduction from parallel to perpendicular loads should be followed.

Clamping Plates

The second type is the so-called clamping plate or tie spacer. The primary use of this connector is as a tie spacer between the guard timber and tie to improve the joint by making it unnecessary to drill bolt holes into all the ties and to eliminate to a large extent the use of bolts or lag screws since the guard timbers are bolted to every third or fourth tie only. In that way, a secure fastening is made which eliminates the shifting or creeping of ties.

This plate is made in two types. The first type is a 14-gage stamped steel plate 5¼ in. square with teeth projecting from both faces. The flat sides of the teeth are all parallel on each face but at right angles on opposite faces so that when installed the broad side of the teeth is parallel with the grain of the wood. The second type or the flanged clamping plate has similar teeth on one face with two edges bent outward on the other face to form flanges. The first type, in other words, has teeth embedded in both the tie and the guard timber, while the second type has teeth in the guard timber only and the flanges which fit over the edges of the tie prevent it from creeping. The choice of type depends largely upon the facilities for installation.

The teeth may be installed either by a driving force or by pressure.

The allowable design loads in pounds for clamping plates based on a factor of safety of four on ultimate test loads when used in dense grades of Douglas fir and southern pine are as follows:

Type of Plate	*Perpendicular to Grain*
Plain clamping plate (with ¾-in. bolt)	3,400
(Plate only)	2,460
Flanged clamping plate (Teeth only)	2,920
(One flange only)	1,610

The two other connectors which have recently been introduced commercially but which do not apply as generally to trestle design are the plain flanged shear plates and the claw plates. These two connectors do apply, however, to the types of joints used in framed timber bridges.

Shear Plates

The plain flanged shear plate is made in two sizes and from two materials. The smaller size is 2⅝ in. in diameter and is made of pressed steel. The larger size is 4 in. in diameter and is made of malleable cast iron. The main feature of these plates is their adaptability to portable or demountable structures. The flanged shear plate is devised so that its back fits flush with the surface of the timber into which it is placed. It can be held in place with small nails fitted into holes provided for the purpose. It is so designed that when used back to back or backed up to a steel plate the full shearing strength of the bolt may be developed.

The allowable design loads in pounds for flanged shear plates based on a safety factor of four on ultimate test loads in dense grades of Douglas fir and southern pine are as follows:

Size Inches	*Bolt Diam. Inches*	*Load Parallel to Grain*	*Load Perpendicular to Grain*
2⅝	¾	3,450	2,590
4	¾	5,080	4,160
4	⅞	6,370	4,160

Improvement in Split-Ring Design

The split-ring connector mentioned in the previous report has been recently improved by an inside bevel and a rounded mill edge. These changes enable the rings to be placed in their grooves much more easily, particularly when several rings are placed in a group. The original load capacities apply to the improved ring. One of the drawings shows the four different connectors which have been discussed here as well as the others described previously in a report of this committee. The other drawing shows suggested applications of connectors to various types of timber construction.

This report is presented as information.

Appendix D

(11) Use of Tar and Asphalt Compositions for Wearing Surfaces on Wood Floored Highway Bridges

G. S. Crites (chairman, subcommittee), W. D. Keeney, J. V. Johnston, W. C. Schakel, T. G. Sughrue.

This subject was assigned to your committee in 1938 and a report was offered in 1939 as information. The information and specifications given were obtained from data furnished by numerous state highway departments and manufacturers of tar and asphalt compositions. The specifications have been revised to conform with the recommendations of the Division of Simplified Practice for aggregates, and follow the tar specifications adopted by the AASHO and others. The subject has been pursued further by the committee and the following additional paragraph appears under the provision for Construction of Asphalt Mat Surface (Mixed Method) Prime Coat.

> Where a fire hazard would be involved in the use of a hot-mixed prime coat, or the application required to be made by railway forces, an asphalt cut-back or asphalt emulsion as per Section II should be used for the prime coat.

Conclusions

Under certain conditions there may be places where the use of tar and asphalt compositions for wearing surfaces on wood floored highway bridges is justified and such use should conform to the best established practices.

It is recommended that these specifications be approved for printing in the Manual and the subject be discontinued.

USE OF TAR AND ASPHALT COMPOSITIONS FOR WEARING SURFACES ON WOOD FLOORED HIGHWAY BRIDGES

General Requirements

Wood subfloor shall be securely fastened to prevent vibration and, unless otherwise specified, all sharp corners, projections or irregularities in surface shall be removed. Wood which is worn or containing defects injurious to the bituminous surface, shall be removed and replaced with new material. Any openings in the floor shall be completely sealed by caulking with oakum, or by other suitable means. All dust, dirt, debris, or foreign material on the surface to be treated shall be removed by sweeping with stiff brooms and if necessary the surface may be flushed with water. If water is used, the subfloor shall be allowed to become thoroughly dry and then swept with stiff brooms before applying the first coat.

Wherever possible, treated timber only should be used, as the extra life is well worth the costs. When freshly treated timber is used, the plank floor shall be allowed to dry out prior to surfacing operations, to prevent softening of the surface coat. As a general precaution, when creosoted timber is used, the priming of the surface with tar or asphalt should be eliminated or reduced in amount to where it will be properly absorbed and not result in cutting back the prime to a lower viscosity. On dry or old creosoted timber, the prime should be reduced to about 0.15 gallon per square yard, depending on the amount of creosote treatment coming to the surface of the planks.

Single-Plank Floors

There are still in use a great many wooden highway bridges having single plank floors, and they are difficult and costly to maintain. Most of these old bridges originally had wooden stringers, to which were nailed 3 inch wooden plank in transverse fashion. As the stringers rotted, new ones were placed, sometimes without removal of the old, so conditions progressively grew worse and occasionally a truck would break through the floor between cross beams. By reconstructing the stringers so as to distribute concentrated loading to the floor beams, and by placing a light wood flooring surfaced with tar or asphalt over them, many such old bridges can be made safe and useful for a long time to come, particularly on light traffic highways.

Single-plank floors work under concentrated loading and are difficult to keep completely sealed. On single planks, cotton fabric is an excellent material to use to prevent the floor cracks from progressing through the bituminous wearing course. No effort should be made to place a thick wearing surface on single-plank floors as the movement of the planks will break up a thick bituminous coating quickly. Rather, a thin, pliable but strongly adhesive coating should be placed, covered with fine aggregate, preferably sharp sand, approved screenings or finely crushed slag.

Double-Plank Floors

The top planks should be at a right angle, or nearly as possible at a right angle to the bottom planks to prevent progressive cracks. The first treatment should consist of as much hot, cut-back or emulsified prime as the floor will absorb without running off. This usually amounts to about 0.5 gallon per square yard; but should be reduced to about 0.25 gallon, or less, per square yard where creosoted timber is used. There should be enough prime, however, to penetrate well through the upper layer of plank, spread over the lower layer and thereby waterproof the joint between. After the absorption of the prime coat a seal of hot, cut-back or emulsified bitumen should be applied at the rate of from 0.1 to 0.2 gallon per square yard, and covered with fine aggregate. Until the aggregate is in proper position, the surface should be lightly broomed; but the final mat should not exceed 0.25 inch thickness.

Vertical Laminated Floors

Two by fours, two by sixes, three by sixes, or even larger sizes of planks are sometimes placed with the greater dimension vertical. If desired, the larger planks can be preshaped so that a crown will be obtained. Each succeeding piece is nailed to the one previously laid with staggered joints until a continuous floor is completed. Locations guide as to whether planks are to be surfaced, partly surfaced or unsurfaced. Unplaned planks have a slightly uneven surface which gives a good anchorage for surface treatment. For such surfaces, bituminous surface treatment as prescribed for double-plank floors may be used. It is possible to increase the mat thickness and apply coarser aggregates if desired. Such floors should be seal-coated before they are put regularly into use; otherwise water will soak into the vertical joints, be retained there and cause swelling.

Grooved Laminated Floors

By alternating the depth of planks in vertical laminated floors, as by using 5-inch and 6-inch or 7-inch and 8-inch planks alternately for lamination, a grooved or cogged floor will result. This type of floor will give a mechanical bond between the planks and the bituminous wearing surface.

Saw-Tooth Laminated Floors

If floor planks of the same depth are milled with a 90-degree ridge uppermost and a laminated floor of saw-tooth effect built with them, a bituminous wearing surface can be applied without its becoming corrugated. Also, there is little liability of the wearing coat creeping or shearing, as the area of the entire surface would have to shear in order to slip on the planks. A floor of such construction allows for a suitable depth of bituminous coat under all conditions.

While laminated floors are somewhat thicker than single plank, they are infinitely stronger, more silent and will give service life much longer than that of flat planks. Also, they are more adaptable to the application of bituminous wearing surfaces.

I

Construction of Tar Mat Surface

Prime Coat—After the subfloor has been prepared as hereinbefore specified and is thoroughly dry, the entire surface shall be covered with a first coat of tar. The tar shall be applied cold at the rate of ¼ gallon per square yard where the plank floor is untreated; but when treated timber is used, the priming coat may be eliminated or reduced to avoid cutting the tar back to a lower viscosity. No traffic shall be permitted to use the surface thus treated. The prime coat shall remain in place 12 hours or more, until it is dry, before applying second application of tar.

Second Coat—The tar shall be heated in an open tank or kettle to a temperature between 150 degrees and 225 degrees F. and applied evenly to the surface at the rate of ½ gallon per square yard. The methods and appliances used shall be such as to insure a uniform distribution of the tar over the surface of the roadway. A suitable pressure spraying device, preferably, shall be employed. Immediately after the tar is sprayed or otherwise deposited upon the roadway surface, it shall be smoothed out to a uniform thickness by means of squeegees, mops or other suitable spreading device. Care shall be taken not to overheat the material, the proper temperature being obtained when it will flow with reasonable freedom and remain fluid for a sufficient period to permit the aggregate to become thoroughly incorporated in the mass.

Immediately after the application of this coat of tar the surface shall be covered with the aggregate at the rate of approximately 0.5 cubic foot per square yard. Accurate measuring or weighing devices shall be provided to insure the proper quantity of aggregate being used. The aggregate shall be spread evenly over the surface by means of square pointed shovels. As soon thereafter as practicable the surface shall be hand tamped or rolled with a heavy hand roller.

After rolling or tamping is completed, if sucessive applications of the tar and aggregates are necessary to obtain the required thickness they shall be applied in the same proportions and in the same manner as specified for the first application. The entire surface shall then be rolled or hand tamped as specified above.

Care shall be exercised to secure a smooth, even surface, free from depressions or irregularities, which when tested with a 10 foot straight-edge shall not vary by more than ¼ inch from the specified surface contour.

The total thickness of the tar mat shall be as specified but in no case shall exceed ¾ inch.

Construction of Asphalt Mat Surface (Mixed Method)

Prime Coat—After the subfloor has been prepared as hereinbefore specified and is thoroughly dry, the entire surface shall be covered with a first or prime coat of asphalt prepared and applied as follows: A known quantity of asphalt shall be placed in an open tank or kettle and heated to a temperature between 250 degrees and 300 degrees F. The fire shall then be drawn and an equal amount of gasoline (high test preferred), or benzine, shall be added to the hot asphalt and the mass thoroughly stirred. The mixture shall then be immediately applied while hot to the floor surface at the rate of ¼ gallon per square yard. No traffic shall be allowed on the treated surface and the material shall be allowed to remain in place for 3 or 4 hours, or until sticky, before applying the second coat.

Where a fire hazard would be involved in the use of a hot mixed prime coat, or the application required to be made by railway force, an asphalt cut-back or asphalt emulsion as per Section II should be used for the priming coat.

Second Coat—There shall be provided a suitable platform for hand mixing and accurate measuring and weighing devices to insure the proper quantities of material being used. The asphalt shall be heated in an open kettle or tank to a temperature between 250 degrees and 325 degrees F. The aggregate shall be heated to a temperature between 225 degrees and 275 degrees F. After the materials are heated to the temperature specified they shall be placed on the mixing platform in the proportion of approximately one gallon of asphalt binder to 0.8 cubic foot of aggregate. The mass shall be thoroughly mixed by hand until all particles of the aggregate are entirely coated with the binder. The mixture shall then be placed immediately on the surface to be treated, spreading it evenly over the surface to the required depth. The entire surface shall then be hand tamped or rolled with a heavy hand roller.

Care shall be exercised to secure a smooth, even surface, free from depressions or irregularities, which when tested with a 10 foot straight-edge shall not vary by more than ¼ inch from the specified surface contour.

The total thickness of the asphalt mat coat shall be as specified but in no case shall exceed ¾ inch.

Application of Seal Coat to Tar or Mixed Asphalt Mats

After the second coat, for either tar or mixed asphalt mats, has been completed, the entire surface shall be given a seal coat of the same bituminous material as specified for the second coat. The bituminous material shall be applied hot and spread evenly over the surface by means of squeegees at the rate of ¼ gallon per square yard. After the seal coat has been applied, a light dressing of clean dry sand, stone screenings or granulated slag shall be spread evenly over it to absorb any excess bitumious material remaining on the surface. In order to hold the maintenance of this type of construction to a minimum, a double liquid seal coat is recommended.

Construction of Asphalt Mat Surface (Penetration Method)

Prime Coat—The first or prime coat of asphalt shall be prepared and applied in the same amount and manner as above specified for the prime coat for mixed asphalt mats.

Second Coat—After the first or prime coat has set sufficiently to become sticky the surface to be treated shall be covered with a thin layer of the aggregate applied over the surface by means of square pointed shovels.

The asphalt shall be heated in an open tank or kettle to a temperature between 250 degrees and 325 degrees F. and applied over the surface covered with the aggregate, at the rate of ½ gallon per square yard. The methods and appliances used shall be such as to insure a uniform distribution of the asphalt over the surface of the roadway. A suitable pressure spraying device, preferably, shall be employed. Care shall be taken not to overheat the material, the proper temperature being obtained when it will flow with reasonable freedom and remain fluid for a sufficient period to thoroughly penetrate the aggregate.

If successive applications of aggregate and asphalt are necessary to obtain the required thickness they shall be applied immediately following the first application. Each application shall consist of a layer of aggregate applied in the manner specified above and an application of hot asphalt applied at the rate of ¼ to ½ gallon per square yard.

Over the final coat of asphalt there shall be spread a layer of clean dry sand, stone screenings, or granulated slag sufficiently thick to prevent bleeding and the entire surface shall then be hand tamped or rolled with a heavy hand roller.

Care shall be exercised to secure a smooth, even surface, free from depressions or irregularities, which when tested with a 10 foot straight-edge shall not vary by more than ¼ inch from the specified surface contour.

The total thickness of the asphalt mat coat shall be as specified but in no case shall exceed ¾ inch.

Opening to Traffic

No traffic shall be allowed on the bituminous mat surface for a period of 24 hours after it has been completed. Tar and mixed asphalt mats shall not be considered as completed until after the application of the seal coat.

Physical Properties

Tar

The first, or prime coat, (cold application), for tar wearing surfaces on wood bridge floors shall be a homogeneous tar conforming to the following requirements:

	Min.	*Max.*
Water, percent	...	2.0
Specific viscosity (Note 1) Engler, 50 cc at 40° C. (104° F.)	8.0	13.0
Total bitumen soluble in carbon disulphide, percent	88.0	...
Distillation test on water free material (Note 2):		
Total distillate, by weight:		
0–170° C. (32–338° F.) percent		7.0
0–270° C. (32–518° F.) percent		37.0
0–300° C. (32–572° F.) percent		45.0
Softening point of residue		60° C.

Note 1—Local conditions of temperature and of the surface to be treated may make advisable a change in the above specified viscosity. In case such change is made the following ranges of specific viscosity are suggested for use:

5–8; 8–13; 13–22; 22–35

Note 2—It is suggested that the maximum requirements for percentages of distillate for tars having a specific viscosity of 22–35 be as follows:

0–170° C.	5 percent
0–270° C.	30 percent
0–300° C.	40 percent

The second coat (hot application) for tar wearing surfaces on wood bridge floors shall be a homogeneous refined tar conforming to the following requirements:

	Min.	*Max.*
Water, percent	...	0.0
Float test at 32° C. (89.6° F.), seconds	120	200
Total bitumen (soluble in carbon disulphide), percent	80.0	...
Total distillate, by weight:		
0–170° C. (32–338° F.) percent		1.0
0–270° C. (32–518° F.) percent		15.0
0–300° C. (32–572° F.) percent		25.0
Softening point of residue		65° C.

The Asphalts for Either Mixed or Penetration Method

Prepared from Petroleum

Specific gravity	Not less than 1.0
Softening point	45–65° C.
Penetration	85–100
Loss at 163° C.—5 hours	Not more than 1%
Ductility	Not less than 50 C M
Soluble bitumen	Not less than 99.5%
Organic insoluble	Not more than 0.2%

Prepared from Native Asphalts

Specific gravity	Not less than 1.03
Softening point	45°–65° C.
Penetration	85–100
Loss at 163° C.—5 hours	Not more than 2.0%
Ductility	Not less than 30 C M
Soluble bitumen	Not less than 94.0%
Inorganic insoluble	2.5–4.0%

Aggregate for Cover Material

The aggregate shall be a clean, tough, durable crushed limestone, trap rock or other suitable stone having a percentage of wear of not more than 6; or a clean crushed slag weighing not less than 70 pounds per cubic foot when compacted to refusal by shaking; or a clean hard, tough gravel, crushed or uncrushed, having a high resistance to abrasion. The aggregate shall be uniform in quality and gradation, free from dust, dirt, clay or other foreign matter. Two sizes, as tested with laboratory sieves shall be used as follows:

Coarse Aggregate Cover Material—The coarse aggregate cover material, No. 8—¾-in. size, shall conform to the following gradation:

Sieve Size (Square Openings)	Total Percent Passing
1-in.	100
¾-in.	90–100
⅜-in.	30–65
No. 4	5–25
No. 8	0–5

Fine Aggregate Cover Material—The fine aggregate cover material, No. 8—⅜-in. size, shall conform to the following gradation:

Sieve Size (Square Openings)	Total Percent Passing
½-in.	100
⅜-in.	85–100
No. 4	10–30
No. 8	0–10

II

BITUMINOUS—CUT BACKS AND ASPHALT EMULSION

General requirements as given in Section I will apply to the use of these materials.

Prime Coat

After the floor has been cleaned and with use of bituminous cut backs, sufficient time should elapse for it to dry before application.

Prime Coat—Approximately ¼ to ½ gallon of bituminous content to the square yard and 24 hours shall elapse before application of the second coat.

In the use of tar cutback, and if practicable, it should be heated to a temperature of 125 deg. to 150 deg. F. to insure more complete penetration and adhesion to the floor.

Application by means of pressure distributors—steam or air—or by means of hand pouring pots.

Second Coat

These materials may be applied by the methods generally termed—Hot Surface treatment for tar; Cold Surface treatment, Mixed-in-Place or Penetration Construction.

Hot Surface treatment for tar to be as specified in Section I.

Penetration Method will follow generally the construction as given in Section I except the asphalt materials shall not be heated.

Mineral aggregate used with bituminous cut backs shall be thoroughly dry before application or mixing is attempted.

Mineral aggregate shall be clean, tough, durable limestone, trap rock or other suitable material having a percent of wear of not more than 5; or a clean crushed slag weighing not less than 70 pounds per cubic foot when compacted to refusal by shaking. The aggregate shall be uniform in quality and gradation and free from dust, dirt, clay and other foreign matter. When tested by means of laboratory sieves it shall conform to the following sizes:

Passing ¾-in. screen, not less than 95 percent by weight.
Passing ½-in. screen, 25 percent to 75 percent by weight.
Passing ¼-in. screen, not more than 15 percent by weight.

Where two course construction is required, the general range of sizes for the bottom course shall correspond to the following:

Passing 1½-in. screen—100 percent.
Passing ½-in. screen—10 percent to 35 percent by weight.
Passing No. 4 screen—4 percent to 16 percent by weight.

Mixed in Place Construction

The mixing shall preferably be done in a batch type concrete mixer, but if a mixer is not available it may be done by hand.

Machine mix—Correct quantity of aggregate shall first be put in the mixer, then proper proportion of the bituminous material added and this allowed to mix until all the aggregate is coated. The entire content of the drum shall be discharged before a new batch is started.

Hand mix—The mixing shall be done on a clean metal or wooden platform. Proper amount of aggregate shall be measured and right proportion of bituminous materials added. The pile shall be cut through from end to end until the aggregate is evenly distributed and uniformly coated.

Increasing density of the mix—If increase in density of the mix is desired, clean, dry, coarse sand may be added, in which case the coarse aggregate shall be mixed as above. The sand shall then be added and the mixing continued until the entire aggregate is evenly distributed and uniformly coated.

Curing and Storing

In storing bituminous cut-back mixed materials for curing, preparatory to use, the depth of the curing pile shall vary according to the length of time the mix is to be stored. If the mix is prepared in comparatively small quantities for immediate use, it shall be stored on clean metal or wooden platforms in piles not to exceed 12 inches in thickness, for a period of from 2 to 5 days. If storage is to be for a longer time, the piles may be made of any depth. A crust will form over the pile, but in rehandling from the storage point to the job the crust will mix with the softer materials underneath and the whole will be in condition for use.

While curing, the mix shall be stored under a shed or protected from rain by tarpaulins or other satisfactory covering, but shall be left uncovered during good weather to permit thorough curing.

Bituminous cut-back products that contain an inflammable solvent should be kept away from open flames.

Emulsified asphalt, except grades specifically prepared shall not be exposed to freezing temperatures and all bituminous material received in barrels shall be thoroughly mixed before use.

Proportion of Mix

The bituminous material for aggregates 1 inch or less shall have the following proportion per cubic yard.

Bituminous cut-backs	12 to 16 gallons
Emulsified asphalts	20 to 27 gallons

In two course construction when larger size aggregates are used, the quantities of the bituminous material may be reduced by 25 percent. The above approximately accounts for emulsifying agent and water in emulsions containing asphalts ranging from 55 to 75 percent.

Seal Coat

Materials and application as in Section I except for emulsified asphalts use damp sand mixed 1½ gallons per cubic foot, spread or brushed evenly over the surface and no attempt made to build a layer, but only to fill voids and seal the wearing course.

EMULSIFIED ASPHALT, PHYSICAL PROPERTIES

				Type		
No.	Test of Emulsion	I	II	III	IV	V
1.	Viscosity, Furol, 60 ml.25°C. Seconds	100–700	20–100	....	....	20–100
2.	Residue by distillation, percent	60–65	55–60	(1)	(1)	55–60
3.	Settlement, 5 days, not more than, percent	5	5	....	....	3
4.	Demulsibility, percent	0–30	0–30	....	....	50–100
5.	Freezing test, 3 cycles	....	....	....	(2)	....
6.	Sieve test, not more than, percent	0.20	0.20	0.20	0.20	0.20
7.	Mixability with water, no appreciable separation in ——— hours	2	2	2	2	....
8.	Coating test	(3)	(3)	(3)	(3)	....

TEST ON RESIDUE FROM DISTILLATION TEST

No.	Test of Emulsion	Type I	Type II	Type III	Type IV	Type V
9.	Penetration at 25°C. (77°F.) 100 grams 5 seconds	100–200	100–200	100–200	125–225	100–200
10.	Soluble in carbon disulphide—not less than, percent	95	95	95	95	95
11.	Ash—not more than, percent	2	2	2	2	2
12.	Ductility at 25°C. (77°F.) not less than, centimeters	40	40	40	40	40
13.	Specific gravity at 25°C. (77°F.) not less than	1.00	1.00	1.00	1.00	1.00

Note: (1) Not less than—65.
Note: (2) Homogeneous
Note: (3) Shall show no appreciable separation in three minutes.
Note: Methods of test—ASTM D-244—Adjustment of above requirements to tentative ASTM D-397, 398, 399 and 401.

Type I—Open-graded coarse aggregate plant mixtures.
Type II—Open-graded coarse aggregate mixed-in-place construction
Type III—For summer use in bituminous concrete mixture for repair work
Type IV—For winter use in bituminous concrete mixtures for repair work
Type V—Penetration macadam and surface treatment work.

III

BITUMINOUS CONCRETE—COLD ASPHALT CONCRETE—LIQUEFIER TYPE

Description

This item shall consist of a "Wearing Course" and a "Bottom Course" premixed for cold-laid asphaltic concrete and furnished in separate lots for the quantities as specified with the coarse aggregates, fine aggregates, hydrated lime, liquefier and asphaltic cement, combined in such proportion as to be within the following general range limits.

General Composition of the Mixtures

The mineral aggregate shall be so graded and the prescribed constituents, prepared as detailed hereinafter, shall be combined in such proportion as to produce a mixture conforming to the following composition limits by weight.

Proportionate Amount (Square Mesh Sieves)	*Bottom Course Percent**	*Wearing Course Percent*
Aggregate passing 1½-in.	100	......
Aggregate retained on 1¼-in.	0–5	......
Aggregate retained on ½-in.	......	0–5
Aggregate passing ½-in.	10–35	......
Aggregate passing No. 4	4–16	15–40
Aggregate passing No. 8	......	10–25
Aggregate passing No. 20	......	5–15
Liquefier	0.2–1.5	0.2–1.5
Hydrated Lime	0.4–1.0	0.5–1.0
Asphalt (Sol. CS_2)	3.0–6.0	4.0–8.0

* Bottom course materials to be used only where thickness is greater than one inch and generally for laminated floor construction and alternate sized edge placed boards are used.

Formula given is a general range of tolerance. This formula may be adjusted to conform to the state highway specifications in general use at the respective location of the company submitting proposals for railway use. The formula as proposed to be used will be furnished, giving type and percent limits for the asphalt and kind of aggregate, with the range of grading wear and toughness. When slag is used for the aggregate, a definite statement is to be given for the percentage of filler added to compensate for its porosity.

Materials

Asphalt Cement—The asphalt cement shall be homogeneous, free from water, shall not foam when heated to a temperature of 347 deg. F., and shall conform to the following requirements:

(a)	Penetration at 77°F., 100 g., 5 sec.	85–100
	Total bitumen (soluble in carbon disulphide), not less than*	95.0%
	Proportion of bitumen soluble in carbon tetrachloride, not less than	99.0%
	Ductility at 77°F., not less than	30 cms.
	Flash point, not less than	347°F.
	Loss at 325°F., 5 hours, not more than	3.0%
	Penetration of residue at 77°F., 5 sec., as compared to penetration before heating, not less than	50.0%

* For Bermudez asphalt cement.

(b)	Penetration at 77°F., 100g., 5 sec.	85–100
	Total bitumen (soluble in carbon disulphide) not less than*	99.5%
	Proportion of bitumen soluble in carbon tetrachloride, not less than	99.0%
	Ductility at 77°F., not less than	30 cms.
	Flash point, not less than	347°F.
	Loss at 325°F., 5 hours, not less than	1.0%
	Penetration of residue at 77°F., 5 sec., as compared to penetration before heating, not less than	60.0%

* For asphalt cement produced from petroleum.

Mineral Aggregate—Mineral aggregate shall consist of clean, tough, durable crushed rock, excluding all but fractured particles, and showing a percentage of wear not greater than 6, and toughness of not less than 6, or air cooled, blast-furnace slag, having a weight per cubic foot not less than 70 pounds.

Hydrated Lime—Hydrated lime shall meet the requirements of the ASTM Standard Specifications, designation, C6–34T.

Liquefier—The liquefier shall meet the following requirements:

1. *During warm weather*—This naphtha shall be a petroleum distillate, which, when distilled in accordance with ASTM D86 shall have an initial boiling point of not over 220 deg. F. and an end point of not over 450 deg. F. At least 45 percent and not more than 55 percent of the distillate shall be distilled over 325 deg. F.
2. *During cold weather*—This naphtha shall be a petroleum distillate which when distilled in accordance with ASTM D86 shall have an initial boiling point of not over 270 deg. F. and an end point lying between 425 deg. F. and 450 deg. F.

With regard to naphtha No. 2, the distillate shall go over continuously at regular intervals between 275 deg. F. and the end point so as to give a line on the distillation graph nearly straight.

Preparation and Transportation

Preparation of Bituminous Material—The bituminous material shall be heated in the melting kettles or tanks so as to secure even heating of the entire mass. The material shall be heated to between 200 deg. F. and 300 deg. F.

Preparation of Aggregates—All aggregate shall be dried to the extent that it has no surface moisture and not more than 0.4 percent of contained moisture. Mixing temperatures of the aggregate shall at no time be less than 45 deg. F. nor more than 110 deg. F., except that when using slag aggregate, the upper limit be raised to 126 deg. F.

Preparation of Mixture—The dried mineral aggregate, prepared as hereinafter described, combined in batches by weighing each separated and screened size, shall be conveyed to the empty mixer. The quantity or character of liquefier used shall be varied within the limits hereinbefore set forth, depending on weather, time and distance the material is to be transported, and shall be used in such manner as will insure the desired constituency of mixture when it is delivered on the project. The aggregate shall be mixed dry for a period sufficient to uniformly distribute the various sizes throughout the batch, after which liquefier shall be sprayed over the aggregate and the mixing continued until all the stone is coated.

The asphalt cement and hydrated lime shall then be successively introduced and the mixing continued until the mixture is thoroughly uniform and homogeneous in character. The dry mixing period shall be set in relation to the aggregate used and the total mixing time will vary in relation to the nature of the aggregates, and the capacity of the mixer but in no case shall the mixing time after the introduction of the asphalt be less than 2 minutes. The mixture shall be so prepared that it may be unloaded and applied at the prevailing temperature down to an air temperature of 45 deg. F., without application of heat.

The mixture shall be uniform in composition, free from lumps or balls of material containing an excess quantity of asphalt and free from pockets containing less asphalt than required. Mixtures for the bottom course and for the wearing course shall be mixed and handled separately.

Transportation of Mixture—All cars shall be in good condition and preferably without pockets. All projecting spikes, nails, foreign material and other obstructions likely to interfere with efficient unloading shall be removed from cars. The bottom of the cars shall be covered with a thin layer of clean sand or screenings. Loaded cars shall be covered with paper or other suitable material; trucks shall be covered with waterproof canvas covers when so ordered. The inside surface of the trucks may be thinly coated with a soapy water, or a mixture of water with not more than 10 per cent of lubricating oil. The use of kerosene, gasoline or similar products will not be permitted.

Shipments found to contain a surplus amount of bituminous material in the bottom of the car or truck will be rejected upon arrival.

Construction

(a) *Prime Coat*—After the subfloor has been prepared as hereinbefore specified and is thoroughly dry, the entire surface shall be covered with a prime coat of asphalt prepared and applied as follows: A known quantity of asphalt shall be placed in an open tank or kettle and heated to a temperature between 250 deg. and 300 deg. F. The fire shall be drawn and an equal amount of gasoline (high test preferred), or benzine, shall be added to the hot asphalt and the mass thoroughly stirred. The mixture shall then be immediately applied while hot to the floor surface at the rate of ¼ gallon per square yard. No traffic shall be allowed on the treated surface and the material shall be allowed to remain in place for three or four hours, or until sticky, before applying the bottom course.

(b) *Bottom Course*—If at the time of laying the surface course mixtures, permanent side support, such as curbs, edging, or gutters have not been constructed, planks of suitable thickness shall be laid along each side and rigidly supported so as to prevent the mixture from being displaced. These planks shall remain in place until final compaction has been obtained. Prior to the arrival of the wearing course mixture on the work, the bottom course shall have been cleaned of all loose and foreign material. The wearing course mixture shall be laid only on a bottom course which is dry, and only when weather conditions are suitable.

Whenever conditions permit, an approved finishing machine shall be used for spreading and leveling both the bottom and wearing courses. Should hand methods of handling and spreading be necessary, the following methods will be required:

Upon arrival on the work, the bottom course mixture shall be deposited on a dumping board outside of the area on which it is to be spread, then spread by suitable means in a uniformly loose layer weighing not less per square yard, per inch designed thickness, than the weight given for the bottom course mixture using aggregates of the specific gravity indicated. Measuring blocks or strips shall be used to insure an even distribution. In special isolated cases, it may be necessary to increase the thickness of the bottom course where laid on uneven wood floors. If such is ordered and the bottom course, measured loose, is of greater depth than 3 inches, it shall be laid and compacted in 2 layers.

For handling and spreading the mixture after being dumped from delivering vehicles on the work, the workmen shall be provided with suitable forks. As soon as practicable after the aggregate is spread, the surface shall be hand tamped or rolled with a heavy hand roller.

The mixture shall be kept clean at all times; dirt or foreign material shall not be allowed to mix with, under, or on the mixture while being unloaded, spread, tamped or rolled. Irregularities in the bottom course shall not exceed ¼ inch as measured with a 10-foot straight edge.

(c) *Wearing Course*—After the compacting of the bottom course, the wearing course shall be spread by forks or other approved methods in a uniformly loose layer so as to cover the underlying course and fill all voids therein. The weight of the wearing course mixture shall be not less per square yard, per inch designed thickness, than the weight of one course mixture as given for the specific gravity of the aggregates used, plus the weight of 0.1 inch (for penetration of top into bottom course).

The compacted bottom course should be covered by the wearing surface as soon as practicable, but not later than 24 hours after it is compacted.

After the wearing course has been spread uniformly even, the entire surface shall then be hand tamped or rolled with a heavy hand roller. If low spots appear in the surface course during compacting, additional mixture shall be spread and the compacting continued until the surface is regular and of even texture. The weight per square yard of the finished two-course surface mixture shall be not less than the weight per square yard, per inch designed thickness, for the bottom and wearing courses, including the allowance for the penetration of the wearing course material into the bottom course.

For the purpose of testing the finished surface, a 10-foot straight edge shall be available on the work. The surface of the top course shall be tested with the straight edge laid parallel to the center line of the roadway upon any portion of the surface, and any depression or other irregularities exceeding ¼ inch shall be satisfactorily eliminated. Such portion of the completed surfaces as are defective in any respect shall be removed and replaced with suitable material.

Upon the compacted wearing surface there shall be spread a layer of clean, dry sand, stone screenings or granulated slag sufficiently thick to prevent bleeding and the entire surface shall then be hand tamped or rolled with a heavy hand roller.

The application of the screenings shall follow the compacting or rolling, of the wearing surface as closely as is practicable, but never on a wet surface.

(d) *A One-Course Surface*—A one-course surface, when specified, shall be constructed of the wearing course mixture directly on the prime coat. The weight of the mixture shall be not less per square yard, per inch designed thickness, than the weight for one-course mixture as given for the specific gravity of the aggregate used. The construction shall be carried out in accordance with the provisions for placing the wearing course of the two-course pavement, the finish, final compression, and testing to be in accordance with the provisions for placing the wearing course of the two-course pavement.

(e) *Extensive Areas*—Where extensive areas of wood floors are to be covered with bituminous materials; or when the wood floor highway bridge is within the limits of highway bituminous material paving projects; after the entire wood surface has been treated with prime coat as specified, the bituminous concrete will be applied to the wood floor under the specifications applying to highway paving projects.

(f) *Protection of Surface Course*—The surfaces shall be protected from traffic until permission is given by the Engineer for the roadway to be opened to traffic.

(g) *Seasonal and Weather Limitation*—No material shall be placed when the air temperature in the shade is below 50 deg. F., except by written permission of the Engineer.

IV

COLD-LAY TAR-CONCRETE PAVEMENT TWO-COURSE CONSTRUCTION

This shall consist of a pavement composed of two courses of cold-laid tar-concrete constructed on a prepared floor.

Composition of mixtures—The several mixtures shall have the following composition:

For Use in	*Bottom Course*	*Top Course*
Tar binder, percent by weight	2.5 to 4.0	6.5 to 8.0
Mineral Aggregate, percent by weight	96.0 to 97.5	92.0 to 93.5

Grading of Aggregate. The total mineral aggregate of the several mixtures, when tested by means of standard laboratory sieves with square openings, shall meet the following requirements, as designated:

For Use In	*Bottom Course*	*Top Course*
Size of Mixture	Intermediate	Fine
Passing No. 200 sieve, percent	......	0–8
Passing No. 60 sieve, percent	......	5–18
Passing No. 20 sieve, percent	......	10–30
Passing No. 8, sieve, percent	0–5	30–55
Passing No. 4 sieve, percent	0–10	50–75
Passing ⅜-inch sieve, percent	......	85–100
Passing ½-inch sieve, percent	10–70	100
Passing 1-inch sieve, percent	70–100	......
Passing 1½-inch sieve, percent	100	......

Uniformity. The several composition limits given above are master ranges of tolerance to govern mixtures made from any raw materials or combinations thereof, proffered for use under these specifications and they are maximum and minimum for all cases. A closer control within these ranges is intended for any specific project. No work shall be started on any specific project nor any mixture accepted, therefore, until the Contractor has submitted and received approval of his intended job mix, indicating in writing the single, definite percentage for each screen and sieve fractions and percent of tar which he chooses as a fixed mean for the project. The submission of such job mix shall, upon approval and thereafter, bind the Contractor to furnish a paving mixture not only within the above master ranges, but also meeting the exact mean percentages thus set up for the project, within allowable job tolerance of: plus or minus ½ percent for tar, plus or minus 10 percent for the ⅜-inch, and for larger sieve requirements, and plus or minus 5 percent for the No. 8 and for the small sieve requirements.

Materials

Tar Binder—The tar binder shall conform to the following requirements:

Sp. Gr., 25°/25° C.	Not less than 1.14
Float Test at 50° C., Sec., (Note A)	40 to 100
Bitumen (Sol. in Car. Disulph.), %	Not less than 75
Distillation, percent by weight:	
To 170° C.	Not more than 1.0
To 270° C.	Not more than 15.0
To 300° C.	Not more than 25.0
Soft. Pt., Ring and Ball, Distillation Residue, °C.	40 to 65.0

Note A: Tar binder used in mixtures for bottom course shall have a float test at 50 deg. C. of not less than 75 seconds. Tar binder used in mixtures for top course shall have a float test at 50 deg. C. of not less than 75 seconds, except that the Engineer may direct that the binder used in top course mixtures shipped in cars or for use in cool weather shall have a float test at 50 deg. C. of 40 to 75 seconds.

Broken Stone—The broken stone shall consist of clean, durable, and angular fragments of rock or boulders, free from an excess of flat or elongated pieces, soft or disintegrated stone, dirt, or other objectionable material. Broken rock shall be produced from rock having a percentage of wear of not more than 6.

The broken stone used in the several mixtures shall be well-graded between the limits of their nominal size, and may be one product or a combination of products of the screening plant which, when combined with filler as specified below, will produce total mineral aggregates for the several mixtures as hereinbefore specified.

Filler—The filler shall consist of sand, rock dust, slag dust, rock screenings or combinations therefore, all of which shall pass a No. 4 sieve, and not less than 75 percent of which shall pass a No. 8 sieve.

Preparation and Transportation

Drying and Temperature of Aggregate—The broken stone shall be dried in a rotating cylindrical dryer. The stone shall be heated by hot gases and not by direct flame to such a temperature and under such conditions that as it leaves the dryer, the stone will be surface dry and contain not more than ½ percent of contained water. Any wet or damp stone coming from the dryer shall be either re-run through the original dryer or through an auxiliary dryer. Covered storage bins for each size of dried stone shall be provided. When combined with the tar binder, broken stone shall be at a temperature of not less than 65 deg. F. and not more than 125 deg. F.

Filler shall be sufficiently dry to be uniformly free-running so that there will be no "balling" when combined with other materials in the mixer. If necessary to drive off moisture by heating, it shall be allowed to cool to a temperature not in excess of 110 deg. F. before use. Rock dust shall be maintained in a substantially dry condition at all times and any material which is wet or contains lumps not readily broken up to powder in the mixer shall be discarded.

Heating and Temperatures of Tar Binder—The binder shall be heated by means of steam coils in the storage tanks to a temperature of 150 deg. to 225 deg. F. As used in the mixture, it shall be at as low a temperature within these limits as will permit thorough coating of the aggregate in a reasonable time. Heating tanks shall be equipped with suitable temperature indicating devices.

Preparation of Mixture—All mixtures shall be proportioned by weight. The components of mixtures shall be conveyed into the empty mixer. In no case shall the mixing time (hereby defined as the interval between the moment when all the ingredients are in the mixture and the opening of the discharge gate) be less than one minute.

The various sizes of broken stone shall be mixed dry for a period sufficient to distribute the various sizes throughout the batch; after which tar binder shall be added through a spray bar with openings at regular intervals over the full width of the mixer or slowly in a thin sheet the full width of the mixer. In preparing fine mixtures, the broken stone shall be thoroughly coated with binder before adding filler, which shall be uniformly distributed over the entire width of the mixer. The mixing operation shall then be continued for the specified time before opening the discharge gate.

The mixture shall be uniform in composition, free from lumps or balls of material containing an excess quantity of tar and free from pockets containing less tar than required.

Transportation of Mixtures—Shipment in cars, trucks, or wagons to follow generally the provisions as given in Section III for one or two-course construction.

Placing Bottom Course—Mixtures shall be laid only where the surface to be covered is dry and only when weather conditions are suitable. The contact surfaces of all curbings and of adjacent pavement edges shall be painted or sealed with approved bituminous material.

Before any rolling is started, the finished surface struck by the machine shall be checked, any inequalities adjusted, all "drippings" i.e., fat sandy accumulations from the screed, and all fat spots from any source, shall be removed and replaced by satisfactory material.

When hand spreading is necessary, the mixture, upon arrival, shall be dumped on approved dump sheets outside of the area on which it is to be spread and shall then be immediately distributed into place by means of suitable shovels and other tools and spread with rakes in a uniformly loose layer of such depth as will result in a completed pavement having the weight per square yard required. Any deviation from standard section shall be immediately remedied by placing additional material or removing surplus as directed.

The material shall then be tamped or rolled and if any depressions appear they shall be filled immediately with additional bottom course mixture and again tamped or rolled until the surface is brought to the required grade and cross-section.

The finished surface of the bottom course shall be such that it will not vary more than ¼ inch from the cross-section of the road, nor from a 10-foot straight edge applied parallel to the center line of the pavement.

Placing Top Course—After the bottom course is compacted, the top course mixture, consisting of the fine mix as hereinbefore described, shall be spread through mechanical spreaders or from dumping boards in a uniform layer to a depth of not more than one inch loose so as to cover the underlying bottom course, fill all voids therein, and produce a completed pavement when rolled or tamped.

If depressions remain after rolling or tamping, more of the mixture shall be added at such points, and firmly compacted into place. After the compacting has been finished, the surface of the top course shall have the required density and thickness and be at the grade established for the surface of the finished pavement.

The finished pavement shall be such that it will not vary more than ¼ inch from the cross-section of the road, nor from a 10-foot straight edge applied parallel to the center line of the pavement.

Protection of Top Course—After the completion of the wearing course, no vehicular traffic of any kind shall be permitted on the pavement until it shall have set sufficiently, and in no case less than 24 hours after placing the bituminous wearing surface.

Report of Committee 8—Masonry

J. F. Leonard, *Chairman,*
F. E. Bates
G. E. Boyd
F. W. Capp
Maurice Coburn
T. L. Condron
Hardy Cross
G. H. Dayett
Theodore Doll
G. F. Eberly
W. K. Hatt
R. Hayes
M. Hirschthal
L. H. Hornsby
A. C. Irwin
M. L. Johnson
J. E. Kalinka
J. A. Lahmer
C. P. Marsh
R. L. Mays
L. M. Morris
O. V. Parsons
I. L. Pyle
W. M. Ray
J. L. Rippey
F. B. Robins
G. E. Robinson
A. N. Laird, *Vice-Chairman,*
C. P. Schantz
G. E. Shaw
G. R. Smiley
A. W. Smith
C. H. Splitstone
E. O. Sweetser
J. H. Titus
Jamison Vawter
L. W. Walter
C. A. Whipple
W. R. Wilson
J. J. Yates
Committee.

To the American Railway Engineering Association:

Your committee respectfully reports on the following subjects:

1. Revision of Manual (Appendix A).

2. Specifications and principles of design of plain and reinforced concrete for use in railway bridges, buildings and culverts, collaborating with Committees 1—Roadway and Ballast, 5—Track, 6—Buildings, 7—Wood Bridges and Trestles, 13—Water Service, Fire Protection and Sanitation, and 15—Iron and Steel Structures (Appendix B).

(a) Composite columns and pipe columns. Progress through the Joint Committee on Concrete and Reinforced Concrete, awaiting the result of a ballot now in progress by that committee on its report.

(b) Rigid frame bridges as related to multiple spans. As a part of the general assignment, Rigid Frame Bridges, the report on Box Abutments is presented as information.

(c) Concrete bridge deck slabs of the non-ballast type, collaborating with Committee 5—Track. Progress report presented as information.

3. Progress in the science and art of concrete manufacture.

(a) Needed adjustments in field practice to use present day cements to best advantage. Progress in study—no report.

(b) The Autoclave test (Appendix C). Progress report submitted as information.

4. Maintain contact with Joint Committee on Concrete and Reinforced Concrete. The members of the Joint Committee have received the final report for ballot approval. After this has been secured it will be presented to the sponsoring bodies, one of which is the AREA, for approval, probably in the early part of 1940.

5. Specifications for foundations, including excavation, cofferdam, piling, etc., collaborating with Committee 1—Roadway and Ballast on soil mechanics, and with Committee 7—Wood Bridges and Trestles on bearing power of wood piles and pile driving (Appendix D). Articles VI, VII and VIII of the Specifications for Pile Foundations, presented last year as information, and revised to meet criticisms which developed since publication, are now recommended for inclusion in the Manual.

6. Methods and practices of lining and relining tunnels, collaborating with Committee 1—Roadway and Ballast (Appendix E). The specifications for lining railway tunnels with brick are presented as information, with the object of recommending their inclusion in the Manual next year.

7. Review specifications for overhead highway bridges of the American Association of State Highway Officials, in so far as they relate to masonry, conferring with that association, and Committee 15—Iron and Steel Structures. Progress in study—no report.

Bulletin 415, January, 1940.

8. Rating of reinforced concrete bridges (Appendix F). The committee regrets its inability to fulfill this assignment adequately, explaining the reasons therefor in its report, with recommendation that the subject be discontinued.

9. Progress in cement manufacture and testing (Appendix G). Presented as information.

10. Specifications for concrete culvert pipe (Appendix H). Recommended specification for the placement of concrete culvert pipe is presented as information.

11. Bibliograhy and review of current engineering literature pertaining to railroad masonry work. Progress in study—no report.

12. Pressure grouting (Appendix I). Presented as information.

13. Specifications for concrete and reinforced concrete railroad bridges and other structures. Progress in study—no report.

14. Specifications for test borings, collaborating with Committee 1—Roadway and Ballast. Progress in study—no report.

The Committee on Masonry,
J. F. Leonard, *Chairman.*

Appendix A

(1) Revision of Manual

G. E. Boyd (chairman, subcommittee), F. E. Bates, F. W. Capp, T. L. Condron, M. Hirschthal, L. H. Hornsby, A. C. Irwin, M. L. Johnson, J. A. Lahmer, F. B. Robins, C. P. Schantz, C. A. Whipple, J. J. Yates.

The committee recommends that the ASTM designation for the Specifications for High-Early-Strength Portland Cement, page 8–5 of the Manual, be changed to C74–38, and that the following changes be made in the specifications:

Delete paragraphs (a) and (b) of Section 9, page 8–7, and substitute a new paragraph.

To Be Deleted

(a) Fineness.—The specific surface shall be determined in accordance with the Tentative Method of Test for Fineness of Portland Cement by Means of the Turbidimeter (ASTM Designation: C115–34T) of the ASTM.[1]

(b) Compressive Strength.—Compressive strength, when specified (Section 5, Option 2), shall be determined in accordance with the Tentative Method of Test for Compressive Strength of Portland Cement Mortars (ASTM Designation: C109–34T) of the ASTM.[2]

---

[1] *Proceedings ASTM, Vol. 35, Part 1, p. 777 (1935); also 1936 Book of ASTM Tentative Standards.*

Proposed Form

Compressive Strength.—Compressive strength, when specified (Section 4, Option 2), shall be determined in accordance with the ASTM Tentative Method of Test for Compressive Strength of Portland-Cement Mortars, Designation C109–34T.[1]

The footnote reference mark at the foot of page 8–7 should be changed from [2] to [1]. Also, the last word in the third line of Section 9 should be changed from "exceptions" to "exception".

The committee recommends that the titles of the specifications appearing on pages 8–87 and 8–89 be revised as follows:

To Be Deleted

[1]*SPECIFICATIONS FOR MAKING PRE-MOLDED CONCRETE PILES*

Proposed Form

[1]SPECIFICATIONS FOR MAKING PRECAST CONCRETE PILES

To Be Deleted

[1]*SPECIFICATIONS FOR DRIVING PRE-MOLDED CONCRETE PILES*

Proposed Form

[1]SPECIFICATIONS FOR DRIVING PRECAST CONCRETE PILES

The committee recommends the deletion of the second paragraph under Article II of the Specifications for Pile Foundations, page 8–117 of the Manual, and the substitution of a new paragraph as follows:

To Be Deleted

Depending upon subsoil conditions, piles consolidate the soil and transfer the load to less firm substrata by skin friction, or act as columns to carry the supported load to the hard substrata.

Proposed Form

Depending on subsoil conditions, piles act as columns to carry the supported load to the hard substrata, or consolidate and transfer the load to less firm substrata by skin friction.

Appendix B

(2) Specifications and Principles of Design of Plain and Reinforced Concrete

A. N. Laird (chairman, subcommittee), T. L. Condron, Hardy Cross, G. H. Dayett, Theodore Doll, R. Hayes, M. Hirschthal, A. C. Irwin, J. E. Kalinka, C. P. Marsh, J. L. Rippey, C. P. Schantz, A. W. Smith, E. O. Sweetser, Jamison Vawter, W. R. Wilson.

Section (a)—Composite Columns and Pipe Columns

The committee reports progress on this subject but is deferring a final report until a definite specification has been approved by the Joint Committee on Concrete and Reinforced Concrete. It is recommended that the subject be continued.

Section (b)—Rigid Frame Bridges as Related to Multiple Spans

The committee report deals with the application of the rigid frame principle to reinforced concrete box abutments for grade separation bridges and is presented as information.

1. Development

In the majority of grade separation projects in municipalities there has been a trend toward increased width of roadways to provide for greater highway vehicular traffic, but no substantial increase in sidewalk widths. Where municipal requirements for highway underpasses formerly consisted of one or two bridge openings of 20 to 30 ft. width, current requirements in heavy traffic sections may consist of clear bridge spans for roadway widths of 60 ft., 80 ft., 90 ft. or more without center piers. Where separate curb piers were used, difficulties of design have been experienced through insufficient bearing area for the steel shoes on tops of piers, interference between abutment and pier

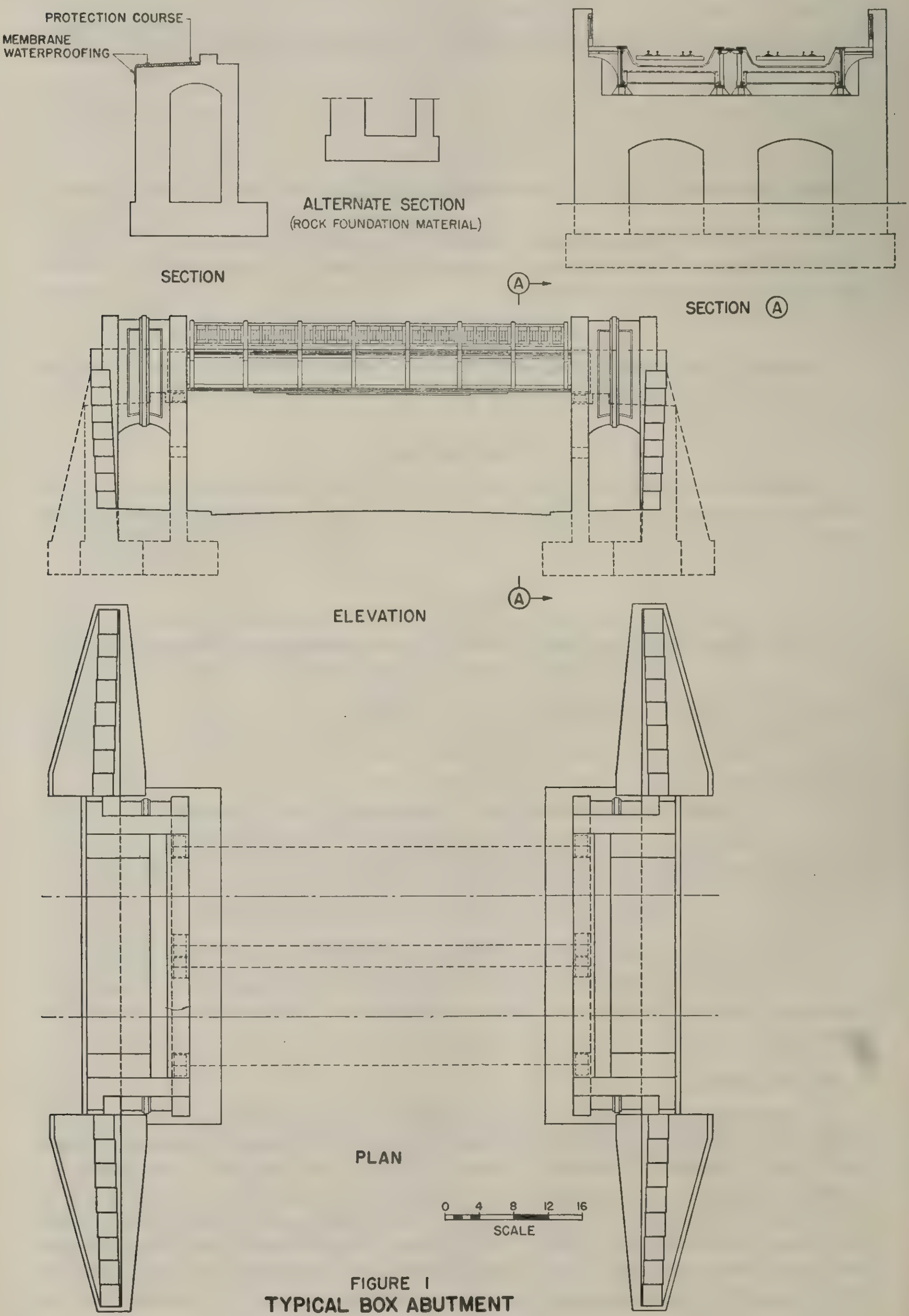
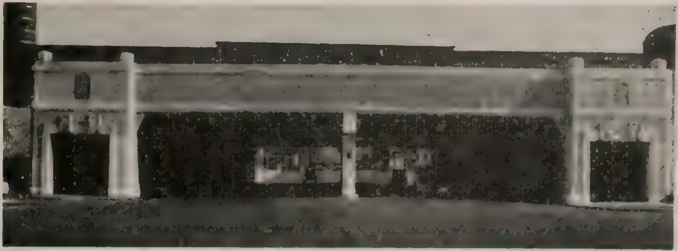


FIGURE 1
TYPICAL BOX ABUTMENT



FIGS. 2 to 5.—Illustrating Applications of Typical Box Abutment Construction.

A

footing slabs, and because the deflections of the roadway and sidewalk spans produce an unsatisfactory joint over the curb piers, particularly on skew spans.

The foundation problem was largely overcome by combining the footing slab of curb pier and abutment. In order to maintain sufficient longitudinal stability however, the abutment section was usually quite heavy, resulting in a footing slab that projected too far to the rear for the best distribution of footing loads.

To meet these requirements, the combination or box abutment was developed. This consists simply of a combination footing slab, a curb pier usually with columns and intermediate openings, and a rear wall slab combined with a deck slab over the sidewalk opening, integral with curb pier.

2. Examples of Box Abutments

Drawing of typical box abutment construction is shown as Fig. 1. Photographs illustrating applications of this form of construction are shown as Fig. 2 to 5, inclusive.

3A. Advantages

(a) Excellent distribution of loads on foundation.
(b) Adequate bearing area for span supports.
(c) Ease of providing for expansion and contraction.
(d) Elimination of short steel span of uneconomical proportions over sidewalk.
(e) Improved waterproofing conditions for deck slab.
(f) Efficient longitudinal rigidity to resist braking and other tractive loads.
(g) Economy in comparison with separate abutment and curb pier.
(h) Eliminates structural difficulties in designing joint between adjacent spans and also distortion of floor system members of skew spans continuous over curb piers.
(i) The box abutment lends itself to architectural treatment and may produce a pleasing structural balance for moderate length and long span grade separation structures.

3B. Disadvantages

(a) Prevents change of curb lines.
(b) May require artificial lighting.

4. Design

The box abutment may be designed as rigid frame.

Careful attention to the details for this construction is necessary. The location and form of construction and expansion joints are particularly important not only from the standpoint of stress distribution but also because of waterproofing requirements. The steel reinforcement should be arranged to avoid sudden changes in stress and to insure adequate facility for placing concrete and compaction. Waterproofing of the roof slab should be treated the same as a bridge deck with non-corrosive metal waterstops embedded in the concrete at all construction and expansion joints and provision made for the movement due to expansion.

Section (c)—Concrete Bridge Deck Slabs of the Non-Ballast Type

Your committee reports progress on the above subject, and presents the following as information and recommends that the subject be continued for further study.

In order to ascertain the advantages of various types of construction of concrete bridge deck slabs of the non-ballast type, the committee prepared a series of sketches of 11 different types of construction for supporting and attaching rails to concrete bridge floors, together with a questionnaire designed to bring out the facts concerning the use

1. Indicate type in service on railroad.

2. Check types that in your jud are practical.

3. Is type of anchorage to conc good, fair or poor?

4. Can anchor bolts be readily in case of derailment or cor

5. Opinion regarding rail faste good, fair or poor?

6. Can fastenings be properly i ed?

7. Is cushion under rail suffic to provide a good riding tra

8. Does rail attachment or cush provide enough vertical spri of the rail?

9. Is type adaptable for crosso and switches?

10. Is sufficient adjustment for alinement and for maintainin alinement provided?

11. Can track surface be maintai

12. Is first cost excessive?

13. Is maintainenance cost exces

14. Can type be used for continu rail bearing?

15. Can slab be satisfactorily w proofed?

LEGEND: G—Good; F—
Y—Yes; N

* Represent replies from railroads

NON-BALLAST TYPE CONCRETE SLAB BRIDGE DECKS

Tabulation of Replies Received to Questionnaire

Types—Letters at tops of columns refer to Figs. A, B, C, etc., appearing in the report

	A	B	C	D	E	F	G	H	I	J	K	Conclusions of Committee
1. Indicate type in service on your railroad.		1*			1*	3*	2*	1*	1*			Majority of types in service have wood ties embodded in concrete with standard rail fastenings.
2. Check types that in your judgment are practical.	2	7 1*	7	7	7 1*	4 3*	2 1*	4 1*	8 1*	7	7	Most practical are those supported on timber ties with standard rail fastenings or track on individual tie plates with fiber cushion on concrete.
3. Is type of anchorage to concrete good, fair or poor?	G 2 F 3 P 4	G 7 F 1* P 1	G 7 F 1 P 1	G 6 F 2 P 1	G 6 1* F 2 P 1	G 4 3* F 1 P 3	G 4 F 2* P 1	G 1 1* F 3 P 3	G 2 F 1* 4 P 2	G 5 F 3 P 2	G 8 F 2 P 1	Most preferable has single anchor bolt through rail clip with split steel or spring washer.
4. Can anchor bolts be readily replaced in case of derailment or corrosion?	Y N 9	Y 1 N 6 1*	Y 1 N 7	Y 1 N 7	Y 1 1* N 7	Y 4 2* N 5	Y 2 1* N 1 1*	Y 3 1* N 3	Y 5 1* N 2	Y 5 N 5	Y 5 N 5	Anchor bolts in concrete difficult to replace.
5. Opinion regarding rail fastenings—good, fair or poor?	G 1 F 2 P 7	G 7 F 2 P 1*	G 5 F 3 P	G F P	G 7 1* F 3 P	G 5 3* F 3 P 1	G 5 1* F 1* P 1	G 4 F 2 1* P 2	G 6 1* F 1 P	G 7 F 3 P 1	G 11 F 2 P	Rail fastening on timber and anchor bolts in concrete considered satisfactory.
6. Can fastenings be properly insulated?	Y 6 N	Y 8 1* N	Y 7 N 1	Y 7 N 2	Y 8 1* N 1	Y 7 3* N	Y 2 2* N 3	Y 5 1* N	Y 8 1* N	Y 11 N	Y 12 N	Majority can be properly insulated.
7. Is cushion under rail sufficient to provide a good riding track?	Y 3 N 5	Y 4 1* N 2	Y 2 N 5	Y 4 N 4	Y 4 1* N 4	Y 7 3* N 1	Y 1 1* N 4 1*	Y 2 N 5 1*	Y 7 1* N 1	Y 10 N 1	Y 6 N 5	Timber types and tie plates with fiber cushions on concrete considered satisfactory.
8. Does rail attachment or cushion provide enough vertical springing of the rail?	Y 6 N 2	Y 3 1* N 4	Y 5 N 4	Y 3 N 5	Y 3 1* N 5	Y 7 2* N 1 1*	Y 1 N 6 1*	Y 4 N 3 1*	Y 6 1* N 1	Y 8 N 1	Y 6 N 5	Timber types or plates with cushion on concrete with spring washer and rail clip with two point bearing on rail and tie plate preferable.
9. Is type adaptable for crossovers and switches?	Y 2 N 5	Y 6 1* N	Y 7 N	Y 7 N	Y 7 1* N	Y 4 1* N 4 1*	Y N 5 2*	Y N 5 1*	Y 8 1* N	Y 7 N 4	Y 6 N 1	Timber types and single anchor bolt type most preferable.
10. Is sufficient adjustment for alinement and for maintaining alinement provided?	Y 7 N 2	Y 3 N 4	Y 4 N 4	Y 4 N 5	Y 4 N 3 1*	Y 7 3* N 1	Y 2 N 5 1*	Y 2 N 5 1*	Y 7 1* N	Y 9 N 1	Y 11 N 1	Timber type and eccentric clip type preferable.
11. Can track surface be maintained?	Y 4 N 2	Y 7 1* N	Y 6 N 2	Y 8 N	Y 7 1* N 1	Y 7 3* N 1	Y 2 1* N 4 1*	Y 5 N 3 1*	Y 8 1* N 1	Y 9 N 1	Y 9 N 1	Practically all types.
12. Is first cost excessive?	Y 2 N 5	Y N 6 1*	Y N 6	Y 1 N 5	Y 2 N 5 1*	Y 2 N 4 3*	Y 2 N 3 1*	Y 1 N 6	Y 1 N 5 1*	Y 2 N 6	Y N 10	None considered excessive.
13. Is maintenance cost excessive?	Y 3 N 5	Y 1 N 4 1*	Y N 6	Y 1 N 5	Y 1 N 5 1*	Y 2 N 3 3*	Y 1 N 4 1*	Y 1 N 5	Y 1 N 5 1*	Y 1 N 5	Y 1 N 8	None considered excessive.
14. Can type be used for continuous rail bearing?	Y 8 N	Y 6 1* N 1	Y 7 N 1	Y 7 N 1	Y 7 N 1 1*	Y 8 3* N	Y 6 2* N	Y 7 1* N	Y 3 N 4 1*	Y 10 N	Y 9 N 2	Majority of types.
15. Can slab be satisfactorily waterproofed?	Y 5 N 2	Y 5 1* N 1	Y 6 N 1	Y 6 N 1	Y 5 1* N 1	Y 6 2* N 1	Y 4 1* N 3 1*	Y 4 N 4 1*	Y 6 N 1 1*	Y 6 N 1	Y 7 N 2	Majority can.

LEGEND: G—Good; F—Fair; P—Poor.
Y—Yes; N—No.

Committee Rating of Various Types

Preferable - Types I, F, B and E.
Fair " K, J, C, D and G.
Poor " A and H.

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* Represent replies from railroads on which the various types were used.

Exhibit A

SUMMARY OF REPLIES AND CONCLUSIONS OF COMMITTEE ON QUESTIONS OF A GENERAL NATURE

Question 1.—Would you recommend rail anti-creepers for long bridge decks of this type?

Replies: Yes 5. No 8.

Conclusion. Anti rail creepers not considered necessary except for unsual cases.

Question 2.—If concrete deck is of considerable length and where rail has continuous bearing, would you suggest reducing the size of rail section because of reduction of rail stresses due to rigidity and continuity of support?

Replies: Yes 1. No 12.

Conclusion. Standard rail preferable.

Question 3.—If the size of rail can be reduced should the same shape be retained? If not, what shape would you suggest?

Replies: Yes 3. No 1.

Conclusion. Same shape rail to be retained.

Question 4.—Do you think it necessary to insulate track where there is no danger of the reinforcing steel coming in contact with the anchor bolts?

Replies: Yes 7. No 6.

Conclusion. Preferable to insulate where bolts are embedded in reinforced concrete slabs.

Question 5.—Do you prefer continuous bearing or individual tie plate bearing for rail?

Replies: Individual 10. Continuous 3.

Conclusion. Individual tie plate bearing preferable.

Question 6.—What type of track approach to the bridge would you recommend?

Replies: Stone ballast 8. Concrete slab 3.

Conclusion. Standard track with stone ballast and specially prepared subgrade preferable.

Question 7.—Will expansion of bridge cause any difficulty?

Replies: Yes 1. No 8.

Conclusion. No difficulty.

Question 8.—Should provision be made for attachment and installation of inner guard rail?

Replies: Yes 12. No 1.

Conclusion. Inner guard rail considered necessary.

Question 9.—In addition to rail cushion should other methods be used to reduce track noises?

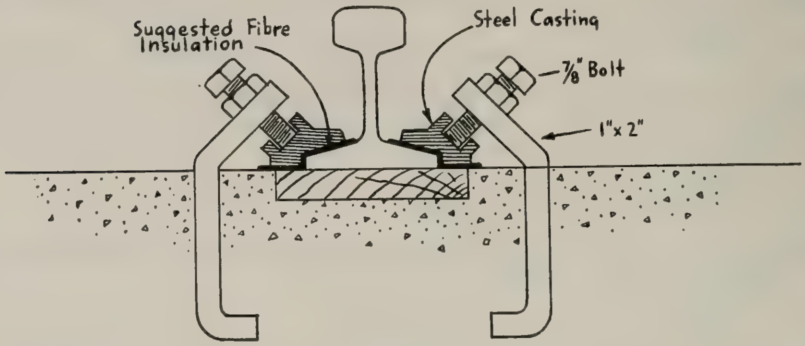
Replies: Yes 1. No 8.

Conclusion. No special provision other than rail cushion necessary to reduce track noises.

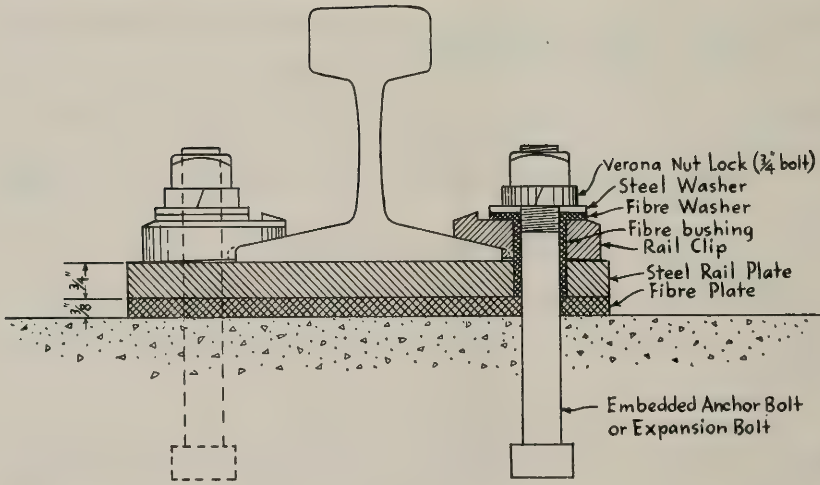
Question 10.—Should continuous rails be provided the full length of the bridge to eliminate rail joints thereon?

Replies: Yes 9. No 3.

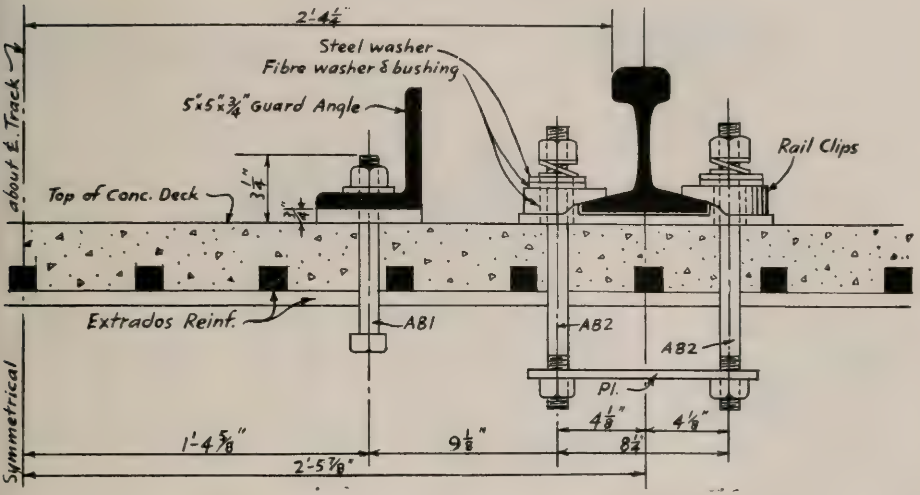
Conclusion. Continuous rails preferable.


Suggested Fibre Insulation
Steel Casting
7/8" Bolt
1"x 2"

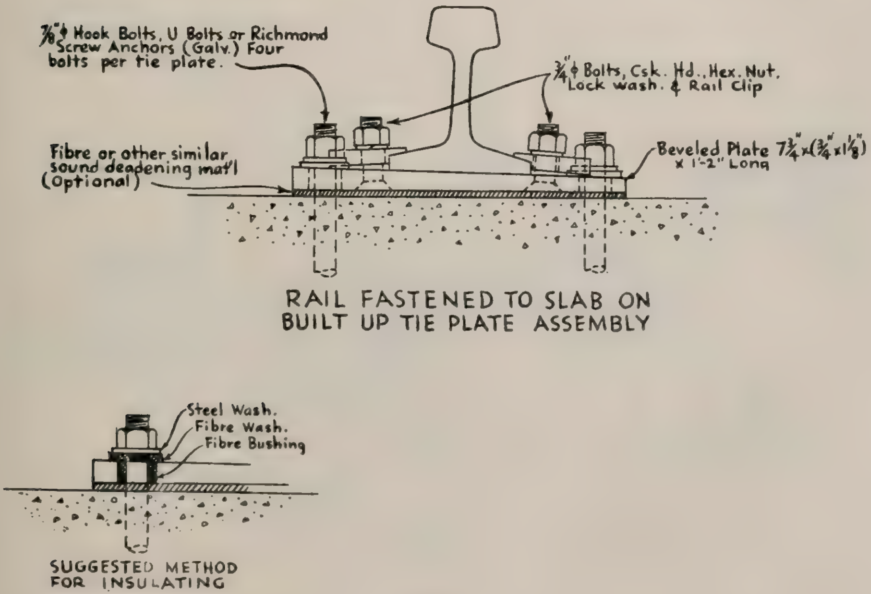
Type A


Verona Nut Lock (3/4" bolt)
Steel Washer
Fibre Washer
Fibre bushing
Rail Clip
Steel Rail Plate
Fibre Plate
3/4"
3/8"
Embedded Anchor Bolt or Expansion Bolt

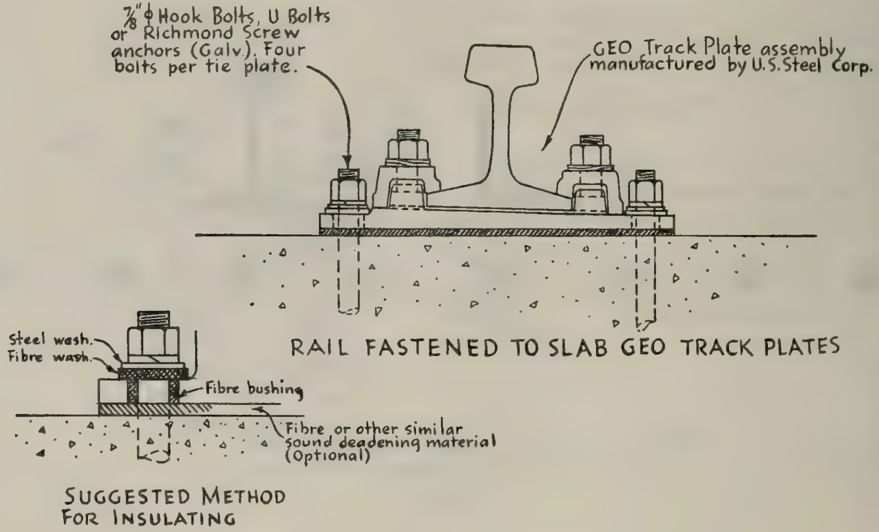
Type B


2'-4 1/4"
Steel washer
Fibre washer & bushing
5"x5"x3/4" Guard Angle
about ℄ Track
Top of Conc. Deck
3 1/4"
3/4"
Rail Clips
Extrados Reinf.
AB1
AB2
AB2
Pl.
Symmetrical
1'-4 5/8"
9 1/8"
4 1/8"
4 1/8"
8 1/4"
2'-5 7/8"

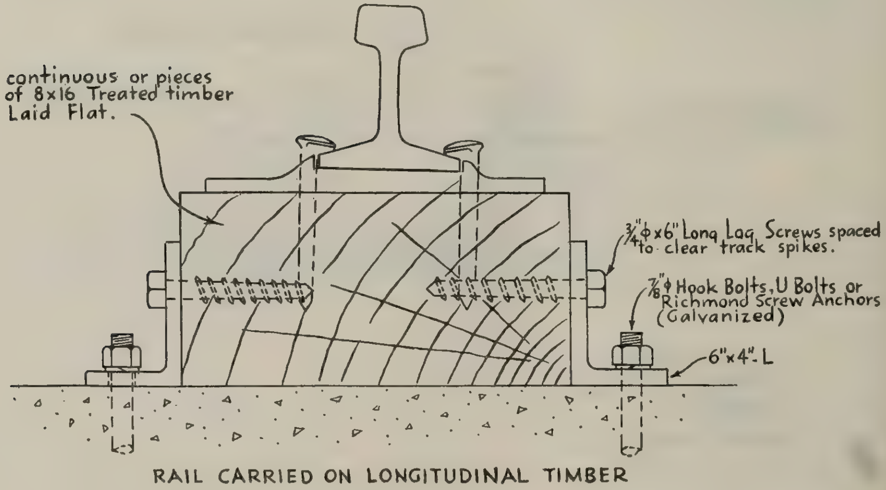
Type C


7/8"φ Hook Bolts, U Bolts or Richmond Screw Anchors (Galv.) Four bolts per tie plate.
3/4"φ Bolts, Csk. Hd., Hex. Nut, Lock wash. & Rail Clip
Fibre or other similar sound deadening mat'l (Optional)
Beveled Plate 7 3/4"x(3/4"x1 1/8") x 1'-2" Long
RAIL FASTENED TO SLAB ON BUILT UP TIE PLATE ASSEMBLY
Steel Wash.
Fibre Wash.
Fibre Bushing
SUGGESTED METHOD FOR INSULATING

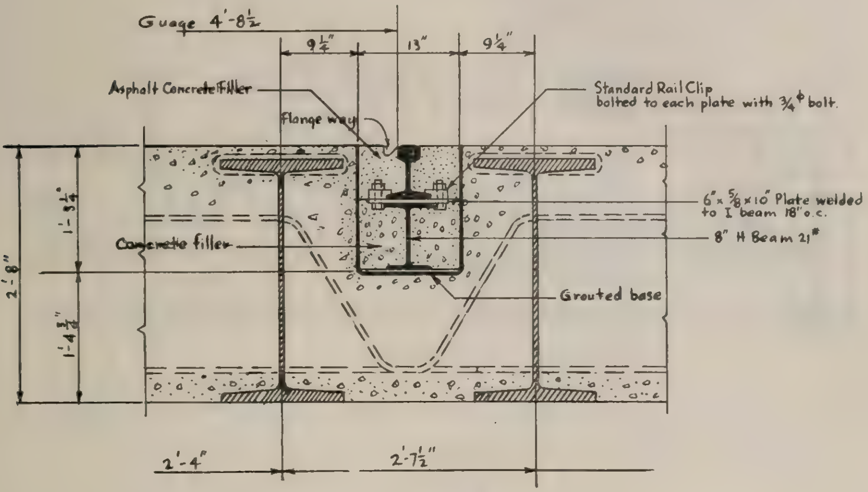
Type D


7/8"φ Hook Bolts, U Bolts or Richmond Screw anchors (Galv.). Four bolts per tie plate.
GEO Track Plate assembly manufactured by U.S. Steel Corp.
RAIL FASTENED TO SLAB GEO TRACK PLATES
Steel wash.
Fibre wash.
Fibre bushing
Fibre or other similar sound deadening material (Optional)
SUGGESTED METHOD FOR INSULATING

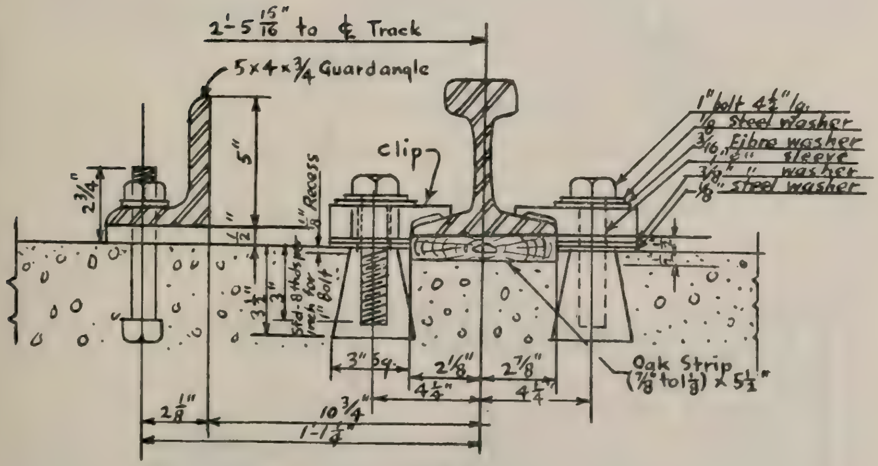
Type E


continuous or pieces of 8x16 Treated timber Laid Flat.
3/4"φ x 6" Long Lag Screws spaced to clear track spikes.
7/8"φ Hook Bolts, U Bolts or Richmond Screw Anchors (Galvanized)
6"x4" L
RAIL CARRIED ON LONGITUDINAL TIMBER

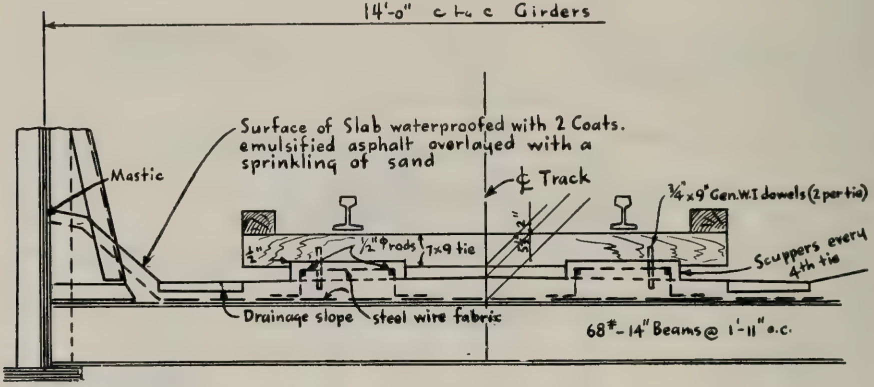
Type F


Guage 4'-8½
9¼"
13"
9¼"
Asphalt Concrete Filler
Flange way
Standard Rail Clip bolted to each plate with ¾ɸ bolt.
6"×⅝×10" Plate welded to I beam 18" o.c.
8" H Beam 21#
Concrete filler
Grouted base
1'-3¼"
1'-4¾"
2'-8"
2'-4"
2'-7½"

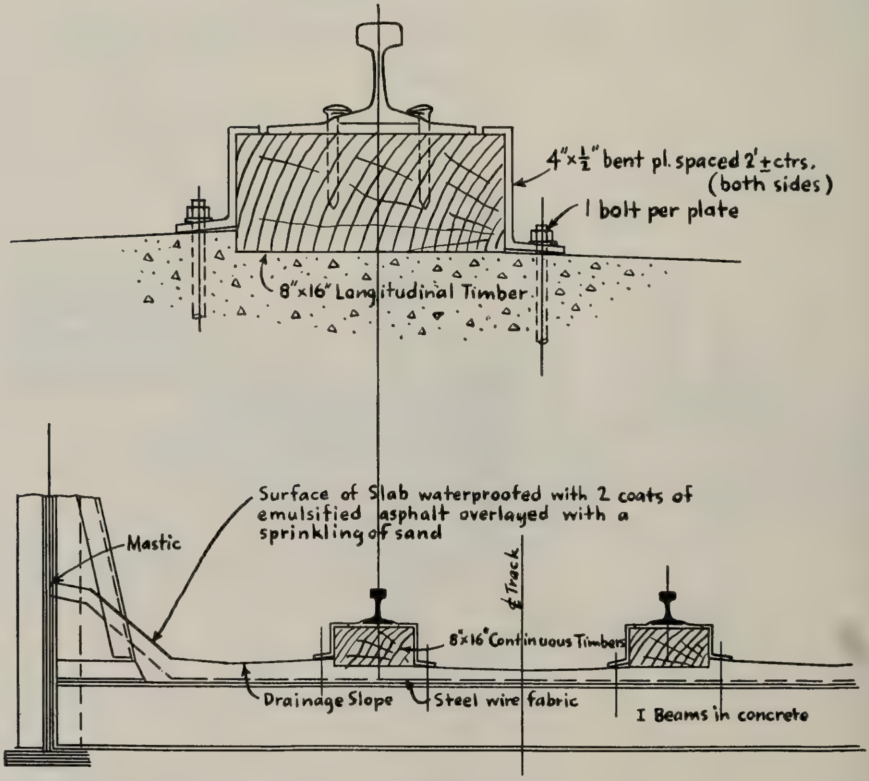
Type G


2'-5 15/16" to ℄ Track
5×4×¾ Guard angle
2¾"
5"
½"
⅝" Recess
Clip
1" bolt 4½" lg.
⅛ Steel washer
3/16" Fibre washer
1⅛" sleeve
3/8" " washer
⅛" steel washer
3½"
3"
Std-8 thds per inch for 1" Bolt
3" Sq.
2⅛"
2⅞"
4¼"
4¼"
Oak Strip (⅞ to 1⅛) × 5½"
2⅛"
10¾"
1'-1¼"

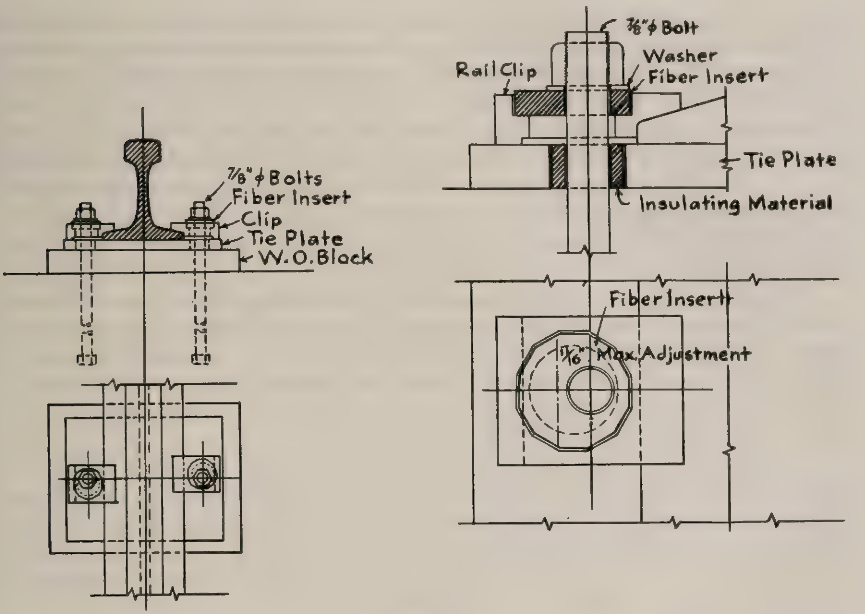
Type H


14'-0" c to c Girders
Surface of Slab waterproofed with 2 Coats. emulsified asphalt overlayed with a sprinkling of sand
Mastic
℄ Track
3/4"x9" Gen.W.I dowels (2 per tie)
5 1/2"
1/2"
1/2" φ rods
7x9 tie
Scuppers every 4th tie
Drainage slope
steel wire fabric
68#-14" Beams @ 1'-11" o.c.

Type I


4"x1/2" bent pl. spaced 2' ± ctrs. (both sides)
1 bolt per plate
8"x16" Longitudinal Timber
Surface of Slab waterproofed with 2 coats of emulsified asphalt overlayed with a sprinkling of sand
Mastic
℄ Track
8"x16" Continuous Timbers
Drainage Slope
Steel wire fabric
I Beams in concrete

Type J



Type K

and service of these various types. The results of the returns received from Class I railroads, and the committee's recommendations are shown on the insert sheet facing page 356 and on page 357, respectively.

Appendix C

(3) Progress in the Science and Art of Concrete Manufacture

L. W. Walter (chairman, subcommittee), F. W. Capp, Maurice Coburn, T. L. Condron, W. K. Hatt, R. Hayes, M. Hirschthal, A. C. Irwin, J. A. Lahmer, C. P. Marsh, L. M. Morris, W. M. Ray, J. H. Titus, C. A. Whipple.

Section 1

Autoclave Test of Portland Cement, Its Significance and Present Status of Proposed Method of Test and Specification Requirement

The early study of the autoclave test of cement as a quality control measure is closely associated with action taken by the Delaware, Lackawanna & Western after investigations made by H. J. Force, chemist for that company. Prior to the investigation instituted by Mr. Force, it had been recognized that a high temperature steam test was more severe than one in which the specimens were subjected to the temperature of steam at atmospheric pressure over boiling water. This test was first used by the Lackawanna in 1909 as a control measure in the construction of the Paulins Kill viaduct on the cut-off line between Hopatcong, N. J., and Slateford, Pa.

In 1912, this same railroad started construction of another line between Scranton, Pa., and Binghamton, N. Y., involving the construction of 83 concrete structures, among which the Tunkhannock and the Martins Creek viaducts were considered exceptionally important. The autoclave test was included in the specifications for the cement used in all the structures on this line and this test requirement remained in the railway's standard specifications until 1925, with the exception that for the structures on the East Orange improvement (1921–23) the autoclave test was waived.

The introduction of this new test requirement, generally known at the time as the Force autoclave test, soon became a matter of keen interest to cement producers and users. In 1913, Mr. Force read a paper before the American Society for Testing Materials under the caption: "Results Obtained with the Autoclave Tests for Cement." This paper was published in the proceedings of the ASTM, Vol. XIII, 1913 (pages 740 to 750). The discussions offered on this paper appear on pages 751 to 796 of the same volume.

It appears that for a period of about 25 years thereafter, there was considerable doubt in the average mind as to the wisdom of adopting this test as a quality control measure. This doubt was due to the lack of analogy between the exposure of cement in the autoclave test and the exposure of concrete in structures, coupled with the lack of convincing evidence that favorable or unfavorable performances of concrete could be associated with definite results in this test.

Careful examination of the Paulins Kill, the Tunkhannock and the Martins Creek viaducts justifies the statement that concrete in these structures has shown splendid performance. The same, however, may be said of the concrete in the East Orange improvement where the autoclave requirement was waived. It is only within the last few years that the autoclave test has again been taken up as a means of ruling out cement of a type which, although passing the present standard soundness test, causes disruptive expansion in concrete.

Following a careful investigation of the type of cracking that resulted from a form of "delayed expansion" in some highway slabs and other structures in limited areas of the United States, it was announced in 1937 that producers of Portland cement in the United States had agreed not to market cement which showed an expansion of more than one percent in neat cement bars subjected, after 24 hours in the molds, to a five-hour autoclave test (three hours at the maximum temperature of 420 deg. F.). Following this, the logical incentive on the part of both users and producers of cement was to consider the adoption of the autoclave test as a standard requirement. Procedure toward this end was begun by ASTM Committee C–1.

A comparison of the high temperature steam test with the present-day standard soundness test is brought out in the report of ASTM Committee C–1 for 1938 and published in the ASTM proceedings for that year.

A brief discussion of the compounds in cement which are affected by high pressure steam is desirable to develop the significance of the autoclave test. Briefly, there are two types of mineral compounds in any Portland cement. First, those which hydrate without appreciable change in volume and produce concrete which has no tendency toward delayed expansion, and second, those which expand materially upon hydration. The normal compounds of calcium with silica, alumina and iron oxide, which comprise the major constituents of Portland cement, are of the first type. Hard-burned lime (CaO) (free lime that recrystallizes at kiln temperatures into hard particles which may not hydrate during the steam test) and crystalline magnesia (MgO), which occur in limited quantities, are compounds of the second type. Under normal temperatures, hard-burned lime and the crystalline MgO hydrate very slowly and the expansions in concrete made with cement containing an undue proportion of these compounds may not be evident until long after the concrete has hardened.

The presence of hard-burned free lime (CaO) cannot be determined by chemical analyses because methods of test now available do not distinguish between lime in this form and the hydrated lime (calcium hydroxide, $Ca(OH)_2$). Calcium hydroxide if present in cements in sufficient quantity renders an analysis for free lime (CaO) meaningless so far as the presence of damaging quantities is concerned. The total MgO in cement is easily determined by chemical analysis but this gives no indication of the extent to which this is in the crystalline form that may be expected to give rise to undue expansions. Thus, some form of physical test is needed to detect the presence of damaging amounts, either of hard-burned free lime or of crystalline magnesia.

The present ASTM soundness test, in which pats are exposed over boiling water, was for many years considered by most people an adequate test for soundness. Free lime, not in the hard-burned state, readily hydrates when neat cement pats (after 24 hours of moist curing) are exposed to steam at atmospheric pressure. The presence, therefore, of undue percentages of free lime in this state will be detected by cracking and distortion of the pats. Free lime in the hard-burned state, however, will not hydrate in steam at atmospheric pressure, so the present test is inadequate where lime in this form is present.

The general tendency in recent years to increase the proportion of lime in the cement raw mix, in order to meet the demands for higher strength at earlier periods, has required burning at higher temperatures to obtain the desired combination of the lime with the other constituents. Under these conditions, when free lime occurs it is likely to be in the hard-burned state. Thus, the autoclave test, which detects the presence of damaging quantities of hard-burned free lime, was the logical suggestion to meet the requirements of present-day cements.

Crystalline magnesia also readily hydrates in the high pressure steam. Its presence in cement in damaging amounts, which would not be detected in the pat test, is indicated by measurable expansions or even complete disintegration in the autoclave test.

Besides this effect of the autoclave treatment on free lime and magnesia, it has recently been discovered that the autoclave also causes tricalcium aluminate (C_3A) to hydrate in a manner that will cause some expansion of the specimen. This compound at normal temperatures has always been considered to have an orderly mode of hydration, similar to the other principal cement minerals. Since it does not contribute to expansion in concrete hydrating at normal temperatures, and yet has a slight expansive tendency in the autoclave, it is apparent that the autoclave test may be unduly severe for cements potentially high in this compound. It cannot be stated definitely to what extent this latter fact may have engendered opposition to the adoption of the autoclave test.

Finally, the significance of the autoclave test may be summed up in the following statements, in which there is now rather general agreement: First, the test is more severe than the present standard pat test; second, it is serviceable in ruling out cement which is unsound due to the presence of damaging amounts of hard-burned free lime (CaO), or of crystalline magnesia (MgO) in a form which chemical analysis will not isolate; and third, the test does not go beyond the detection of unsoundness and should not be considered as a cure-all against possibilities of inferior cement.

The test has not been accepted by Committee C–1 of the ASTM nor has any requirement for an autoclave test been introduced into ASTM specifications for cement. The difficulty appears to be lack of agreement among the committee members as to whether a qualitative or a quantitative test is desirable, and if a quantitative test, what limits should be imposed on the expansion.

There is presented, herewith, a copy of the suggested method of test for autoclave expansion of Portland cement, as published for information in Vol. 38, 1938, ASTM Proceedings, pages 297–300.

PROPOSED METHOD OF TEST FOR AUTOCLAVE EXPANSION OF PORTLAND CEMENT[1]

As published in Volume 38, 1938, ASTM Proceedings, pages 297 to 300, inclusive, as information only.

Scope

1. This method of test is intended for determining the soundness of Portland cement by means of an autoclave test on 1 by 1-in. neat-cement specimens.

Scales

2. (a) The scales used in weighing materials for the neat-cement mixes shall conform to the following requirements: On scales in use the tolerance for a load of 1,000 g. shall be plus or minus 1.0 g. The tolerance on new scales shall be one-half of this value. The sensibility reciprocal[2] shall not be greater than twice the tolerance.

(b) The tolerances on the weights in use in weighing materials for neat-cement mixes shall be as follows:

Weight	*Tolerance + or —*	*Weight*	*Tolerance + or —*
1,000 g.	0.5 g.	100 g.	0.15 g.
900 g.	0.45 g.	50 g.	0.10 g.
750 g.	0.4 g.	20 g.	0.05 g.
500 g.	0.35 g.	10 g.	0.04 g.
300 g.	0.3 g.	5 g.	0.03 g.
250 g.	0.25 g.	2 g.	0.02 g.
200 g.	0.20 g.	1 g.	0.01 g.

The tolerances on new weights shall be one-half these values.

Glass Graduates

3. Glass graduates of 250-ml. capacities used for measuring the mixing water shall be made to deliver the indicated volume at 20 deg. C. (68 deg. F.). The tolerances on these graduates shall be plus or minus 2 ml. The main graduation lines of the cylinders shall be circles and shall be numbered. The least graduations shall extend at least one seventh of the way around and intermediate graduations shall extend at least one-fifth of the way around.

Molds

4. (a) Molds may be the single, double, or gang-mold type that will provide 1 by 1-in. test specimens of 10-in. effective gage length. The effective gage length shall be considered as that length between the innermost points of the metal inserts used as reference points. The parts of the mold shall be tight fitting and firmly held together when assembled. The molds shall be made of hard metal not readily attacked by the cement paste. There shall be sufficient material in the sides of the molds to prevent spreading or warping.

(b) Each end plate of the molds shall be equipped to hold properly in place during the setting period a stainless steel or non-corroding metal reference point having a diameter of ¼ in. The reference points shall be set so that their principal axes coincide with the principal axis of the test specimen and shall extend into the specimen ⅝ in.[3]

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[1] Under the standardization procedure of the society, this method is under the jurisdiction of the ASTM Committee C-1 on Cement.

[2] The sensibility reciprocal is a measure of the sensitivity of a balance, and is the weight required to move the position of equilibrium of the beam, pan, pointer, or other indicating device of a scale a definite amount at the capacity or at any lesser load. For a complete definition of sensibility reciprocal, see the Nat. Bur. Standards Handbook M85, pp. 80 to 82.

(c) The distance between opposite faces of the molds shall be 1 ± 0.03 in. The height of the molds, measured separately for each specimen compartment, shall be 1 ± 0.03 in. for both new molds and molds in use. The distance between the inner ends of the reference points shall be 10 ± 0.1 in.

Autoclave

5. (a) The autoclave shall consist of a high-pressure steam boiler equipped with an automatic pressure control and a safety valve. The capacity of the heating unit shall be such that the pressure of the saturated steam in the autoclave may be raised in 1 to 1¼ hours with maximum load from atmospheric to a gage pressure of 295 lb. per sq. in. (absolute pressure about 310 lb. per sq. in.). The automatic pressure control shall be capable of maintaining a pressure of 295 ± 5 lb. per sq. in. for at least 3 hours. A gage pressure of 295 ± 5 lb. per sq. in. corresponds to a temperature of 215.7 ± 1 deg. C. (420.3 ± 2 deg. F.).

(b) There shall be used in the autoclave such a quantity of water as will maintain saturated steam vapor for the entire time of test. The autoclave shall be designed to permit the pressure to drop from 295 lb. per sq. in. to less than 10 lb. per sq. in. in 1 hr. after the heat supply has been shut off.

(c) The autoclave shall be equipped with a vent valve for allowing the escape of air during the early part of the heating period and for releasing any steam pressure remaining at the end of the 1-hour cooling period.

Length Comparator

6. Changes in length of the test specimens shall be measured by a dial gage or micrometer comparator having a range of at least 0.3 in. The instrument shall be graduated to 0.0001 in. and when tested at any points throughout its range the error shall not be greater than ± 0.0004 in. The difference between repeated measurements shall not be greater than 0.0001 in.

Temperature and Humidity

7. The temperature of the molding room and dry materials shall be maintained at not less than 20 deg. C. (68 deg. F.) and not more than 27.5 deg. C. (81.5 deg. F.). The temperature of the mixing water and moist closet shall not vary from 21 deg. C. (70 deg. F.) more than 1.7 deg. C. (3 deg. F.). The moist closet or moist room shall be so constructed as to provide storage facilities for test specimens at a relative humidity of not less than 90 percent.

Preparing Molds

8. Molds shall be thinly covered with petroleum jelly or stearic acid paste;[4] and the stainless steel or non-corroding metal reference points shall be set, care being taken to keep them clean.

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[3] The requirements in Section 4 (a) and (b) fix the length of the specimen at 11¼ in. Uniformity in equipment and procedure is essential if comparable results are to be obtained in different laboratories, and the committee, therefore, recommends adherence to the above requirements.

[4] Stearic acid paste is made by adding stearic acid powder to heated kerosene until a mushy consistency is obtained after cooling. When cooled, this paste shall be applied with a stiff brush.

Mixing Cement Paste

9. The standard batch of neat-cement paste shall consist of 800 g. of cement mixed with sufficient water to give a paste of normal consistency, in accordance with the procedure described in Sections 25 to 28 of the Standard Methods of Sampling and Testing Portland Cement (ASTM Designation: C–77 of the American Society for Testing Materials.[5]

Molding Test Specimens

10. Immediately following completion of mixing, two test specimens shall be molded in three equal layers, each layer being compacted with the forefinger by pressing the paste into the corners, around the reference inserts and along the surfaces of the mold. A total of 100 strokes of the forefinger shall be applied to each layer, moving from one end of the bar to the other and back two times, applying 25 strokes each trip over the length of the bar. After the top layer has been compacted, the paste shall be cut off flush with the top of the mold and the surface smoothed with a few strokes of the trowel. During the operation of mixing and placing, the hands shall be protected by rubber gloves.

Storage of Test Specimens

11. After the mold has been filled, it shall be immediately placed in a moist closet or moist room at a temperature of 21 ± 1.7 deg. C. (70 ± 3 deg. F.) and a relative humidity of at least 90 percent. Specimens shall remain in the molds for at least 20 hours; if removed from the molds before 24 hours they shall be kept in the moist closet or moist room until tested.

Testing

12. (a) At 24 ± 0.5 hour after molding, the specimens shall be removed from the moist closet one at a time, measured for length, and placed in the autoclave in a rack so that the four sides of each specimen are exposed to saturated steam in the same manner.

(b) The temperature of the autoclave shall be raised at such a rate as will bring the pressure of the steam from atmospheric to 295 lb. per sq. in. in 1 to 1¼ hours. To permit air to escape from the autoclave at the beginning of the test period, the vent valve shall be left open until steam begins to escape and then closed. The 295 ± 5 lb. per sq. in. pressure shall be maintained for 3 hours. At the end of the 3-hour period at a pressure of 295 lb. per sq. in. the heat supply shall be shut off and the autoclave allowed to cool at a rate such that the pressure will gradually fall to less than 10 lb. per sq. in. in 1 hour. At the end of the 1-hour cooling period any small pressure remaining shall be released slowly (in about 2 to 5 min.) by opening the vent valve until atmospheric pressure is attained. The autoclave shall then be opened and the test specimens immediately placed in boiling water. The water surrounding the bars shall then be slowly tempered with cool water at a rate such that the temperature of the water and specimens will be lowered to 21 deg. C. (70 deg. F.) in 15 min. The water surrounding the specimens shall be maintained at 21 deg. C. (70 deg. F.) for an additional 15 min., when the specimens shall be surface dried, and measured for length.[6]

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[5] 1937 Supplement to Book of ASTM Standards, p. 54.

[6] If laboratories prefer to make all measurements at 26.5 deg. C. (80 deg. F.), it is recommended that upon removal of the specimens from the moist closet, they be placed in water maintained at 26.5 deg. C. (80 deg. F.) for at least 15 min., measured for length and then placed in the autoclave. Upon removal from the autoclave the bars and boiling water shall be cooled to 26.5 deg. C. (80 deg. F.) in 15 min. and kept in water at this temperature for an additional 15 min. and then measured for length.

Calculation of Autoclave Expansion

13. The difference in length of the test specimens before and after autoclaving shall be expressed as a percentage of the effective gage length and shall be reported to the nearest 0.01 percent. The average of the expansions of the two companion test specimens shall be considered the autoclave expansion of the cement. Any test in which the percentage expansions of the individual specimens differ more than 0.05 shall be repeated.

Appendix D

(5) Specifications for Foundations

Jamison Vawter (chairman, subcommittee), F. E. Bates, T. L. Condron, Hardy Cross, G. H. Dayett, G. F. Eberly, L. H. Hornsby, R. L. Mays, O. V. Parsons, G. R. Smiley, C. H. Splitstone, C. A. Whipple, W. R. Wilson, J. J. Yates.

Last year Articles I to V inclusive, Specifications for Pile Foundations, were adopted for publication in the Manual. Articles VI, VII and VIII were submitted as information and are presented below, with a few minor changes, with the recommendation that they be adopted and published in the Manual. It is recommended that the subject be continued.

SPECIFICATIONS FOR PILE FOUNDATIONS

VI TYPES OF PILES

(A) Timber

Timber piles shall conform to the "Specifications for Wood Piles" pages 7–1 to 7–4 of the Manual of the American Railway Engineering Association.

(B) Concrete

1. Pre-cast

(a) Manufacture. The manufacture of pre-cast concrete piles shall conform to the "Specifications for Making Pre-cast Concrete Piles", page 8–87 of the Manual of the American Railway Engineering Association.

(b) Design. Pre-cast piles shall be of an approved design.

Piles of constant cross-section shall have a least diameter or lateral dimension of 14 inches for piles up to 35 feet in length and not less than 16 inches for lengths over 35 feet and not over 50 feet. Piles over 50 feet in length shall be of a size and design approved by the Engineer. The pile may be pointed or not as the Engineer directs.

Piles with a uniform taper shall have a minimum lateral dimension of not less than 8 inches at the point and an average diameter of not less than 12 inches for lengths not over 40 feet. Piles over 40 feet shall have a minimum taper of 1 inch in 8 feet and a lateral dimension at the point of not less than 10 inches.

The reinforcement shall consist of longitudinal bars, supported by lateral reinforcement in the form of hoops or spirals. The longitudinal reinforcement shall be designed for handling stresses and shall normally consist of 8 bars, uniformly spaced, and not less than ½ inch nor more than 1 inch in size. The cross-sectional area of the longitudinal reinforcement shall be not less than 1 percent nor more than 4 percent of the average gross cross-sectional area of the pile. The lateral reinforcement shall consist of not less than No. 7 steel wire, spaced not more than 8 inches center to center throughout the length of the pile, except that for not less than 2 feet at each end the spacing shall not exceed 3 inches center to center. The reinforcement shall be placed with a cover of not less than 1½ inches and greater cover as conditions require. Steel reinforcement shall conform to the AREA Specifications for Steel Reinforcement as given on pages 8–2 and 8–3 of the Manual.

(c) Cut-off. Pre-cast piles shall be driven to or cut off within 2 inches of the elevation shown on plans, but in all cases the cut-off shall be below any indication of fracture. If piles are cut off or driven below the required elevation, the pile shall be built up to the cut-off line in a manner satisfactory to the Engineer.

2. Cast-In-Place

(a) Types. Cast-in-place piles may be tapered piles in metal cases, cylindrical piles in metal cases or uncased cylindrical piles. Where steel cylindrical shells are used, $\frac{5}{16}$ inch thick or more, they shall be classed as steel piles and are specified under Section 2 Article VI (C).

(b) Tapered Piles. Tapered piles shall be not less than 8 inches in diameter at the tip and the diameter shall be uniformly tapered at the rate of 1 inch in 4 feet for shells up to 40 feet in length, and not less than 1 inch in 8 feet for shells over 40 feet in length. Piles between 40 feet and 56 feet in length shall have a minimum average diameter of 12 inches. Piles over 56 feet in length shall be of a size and design approved by the Engineer. When driving without a mandrel the tips shall have a steel driving point welded to the shell. The shells shall be in one integral piece or adequately spliced. The large end shall be thoroughly reinforced to withstand driving.

(c) Cylindrical Piles. Piles of constant cross-section shall have a minimum diameter of 14 inches for lengths up to 35 feet, and 16 inches for lengths over 35 feet and not over 50 feet. Piles over 50 feet in length shall be of a size and design approved by the Engineer.

Piles with shells pulled may be used where specified. Where shells are to be pulled they shall be equipped with shoes of approved design.

(d) Metal Casings. The metal casings or shells shall be formed of basic open hearth steel. The metal of shells driven with a mandrel shall have a thickness of not less than No. 18 B.W.G. The metal of shells which are driven directly shall have a thickness of not less than No. 7 B.W.G. except where fluted shells are used the minimum thickness may be No. 11 B.W.G. In all cases the thickness shall be sufficient to withstand the driving without failure.

(e) Placing Concrete. Shells must be inspected and approved by the Engineer immediately before any concrete is placed. They must be clean and free of any water or foreign matter. They must be undistorted and of the specified dimensions. The concrete shall be Class 2500 and the placing shall be continuous from tip to cut-off elevation. Where shells are pulled the concrete shall be placed during pulling. Segregation in depositing shall not be permitted.

Reinforcement shall not be used unless especially specified.

No cast-in-place pile shall be filled with concrete until all adjacent piles within a radius of 4½ times the average pile diameter, or not less than 5 feet, have been driven to the required resistance.

After a shell has been filled with concrete, no shell or pile shall be driven within 15 feet thereof until at least 4 days have elapsed.

(f) Allowable Load. The allowable load per pile shall be determined as specified in Article IV but shall not exceed 600 pounds per square inch for the area at the average diameter of tapered piles, 400 pounds per square inch for cased cylindrical piles and 300 pounds per square inch for uncased cylindrical piles.

(C) Steel

Material. All steel used for piles shall conform to the AREA Specifications for Structural Steel.

The concrete used in pipe piles shall conform to the AREA Specifications for Concrete, Plain and Reinforced. Concrete shall be Class 2500.

1. H-Sections

(a) Size. The minimum depth of section shall be 8 inches. The minimum thickness of metal in the web or flange shall be ⅜ inch. The ratio of the flange width to depth of section shall not be less than 85 percent.

(b) Splicing. Full length piles shall be used where practicable, but if splices cannot be avoided, an approved method of splicing shall be used. Piles shall not be spliced except by permission of the Engineer.

(c) Capping. Where steel bearing plates are required they shall be suitably fastened to the top of the piles so as to avoid displacement and to provide as practically as possible an even bearing on the pile with at least 50 percent of the pile top in contact with the bearing cap. The bearing plate shall be of such size that the bearing on the footing concrete shall not exceed 1,000 pounds per square inch. Tops of piles shall project not less than 12 inches into the concrete.

Piles which extend several feet into a concrete footing may be bonded to the concrete by means of a mat of reinforcing bars running through holes in the piles.

(d) Protective Encasement. Piles shall be protected from corrosion by means of concrete encasement extending at least one foot above ground or normal water line and three feet below the ground or minimum water line. The minimum concrete cover shall be 3 inches.

Structural steel piles shall not be used through cinder or ash fill or other active rust inducing material without adequate provision for the protection of such piles, unless laboratory tests of these materials prove the material to be practically free of inorganic acids.

(e) Allowable Load. The allowable load per pile shall be determined as specified in Article IV. The unit stress on H-Section piles shall not exceed 10,000 pounds per square inch for primary loads. Due allowance shall be made for any bending or column action as specified in Section 4 Article III.

2. Pipe Piles (Steel Pipes Filled with Concrete)

(a) Size. Pipe shall have an inside diameter of 10 inches or more and a thickness of not less than ⅜ inch, except that a thickness of $\frac{5}{16}$ inch may be used on 10 inch and 12 inch pipe.

(b) Splicing. Splicing shall be of an approved design. Ends of pipes shall be faced perpendicular to the axis and held together at splices by sleeves. Sleeves should be a tight driving fit on or in the pipe and should extend a distance equal to the diameter of the pipe, above and below the splice. Means should be provided for prevention of movement of the sleeve during driving of the pile.

(c) Capping. Tops of piles shall project not less than 12 inches into the foundation concrete.

(d) Placing Concrete. Inside of pipes must be cleaned of any foreign matter before concrete is placed. The placing of concrete shall be continuous from tip to cut-off elevation. Segregation in depositing shall not be permitted.

No pipe pile shall be filled with concrete until all adjacent piles within a radius of 4½ times the average pile diameter, or not less than 5 feet, have been driven to the required resistance.

After a pipe has been filled with concrete, no pipe or pile shall be driven within 15 feet thereof until at least 4 days have elapsed.

(e) Allowable Load. The allowable load per pile shall be determined as specified in Article IV. The allowable load on the pile shall not exceed 400 pounds per square inch on the concrete and 6,000 pounds per square inch on the steel, provided that in computing the effective area of the steel the outer ⅛ inch of thickness shall be deducted from the thickness of the pipe; except the total load carried by the steel shall not exceed one-half of the total load on the pile. If the length of a pile is more than 40 diameters, the limit of load specified in this paragraph shall be reduced by one percent for each diameter in length in excess of 40 diameters. If splices below the upper section are closer than 20 feet, the allowable load on the pile shall be reduced 5 percent for each splice in excess of the number required for 20 foot spacing. No interior steel reinforcement shall be used.

(D) Composite Piles

Composite piles shall consist of a combination of any two types of piles covered in this specification. The minimum dimensions of each part shall be the same as specified for piles of its type. The allowable load shall be limited by the strength of the weaker type. The joint between the two types shall be such as to prevent their separation, maintain alinement and support the load. All details of the joint, method of driving and the design of composite piles shall be subject to the approval of the Engineer.

VII DRIVING

1. Piles shall be driven with the heaviest hammer that in the judgment of the Engineer, can be used to secure maximum penetration without damage to the pile.

2. Timber and concrete piles shall be protected with an approved cushion cap while being driven.

3. Followers, if used, shall be of steel or iron with a suitable socket to protect the head of the pile. Damaged portions of the pile head shall be removed, and the head properly prepared before the follower is placed.

4. The excavation for pile foundations, where practicable, shall be made to or below the elevation of the cut-off of the piles before the piles are driven.

5. Piles may be jetted, where conditions warrant, but they should be driven to the final penetration as determined by the test piles, or driven to refusal.

The number of jets and size of nozzle and the volume and pressure of water shall be determined by the Engineer.

6. Any pile so injured in driving or handling as to impair its structural integrity as a pile under the conditions of use shall be replaced by a new pile, or the injured part replaced by splicing or other remedial measures adopted—all as directed by the Engineer. Unless otherwise called for on the plans, piles shall be driven as nearly as possible in a plumb position. Any pile so out of line or plumb as to impair its usefulness shall be pulled and redriven or an additional pile driven, as required by the Engineer.

7. On sloping ground or under difficult conditions of driving the pile shall be started in a hole, or guiding templates or other means provided if necessary to insure driving in proper location and line.

VIII SPACING OF PILES

Piles shall be spaced so as to distribute their loads to the supporting materials according to Section 2 Article IV. The minimum center to center spacing shall be not less than 2½ times the butt diameter or side, or 2½ times the depth of steel H-sections. Where practical, piles should be so spaced as to equalize their loads.

Appendix E

(6) Methods and Practices of Lining and Relining Tunnels

I. L. Pyle (chairman, subcommittee), G. E. Boyd, F. W. Capp, Maurice Coburn, G. F. Eberly, A. C. Irwin, L. M. Morris, O. V. Parsons, G. R. Smiley, J. H. Titus.

SPECIFICATIONS FOR LINING RAILWAY TUNNELS WITH BRICK

I GENERAL

Scope

1. These specifications cover the lining of new tunnels and the relining of old tunnels through ordinary formations which involve no special features.

II MATERIALS

Brick

2. Brick shall be vitrified, size approximately 3 inches by 4 inches by 8½ inches. The brick shall have a crushing strength of not less than 6,000 pounds per square inch and, when broken in two parts and immersed in water for 24 hours, shall not absorb in excess of 3 percent by weight.

Mortar

3. Mortar shall be composed of 1 part Portland cement, and approximately ½ part dry lime hydrate or an equivalent amount of lime putty, and 5 parts sand, measured by loose volume.

Cement

4. Cement for mortar shall meet the requirements of the AREA Specifications for Portland cement. Cement that has hardened or partially set shall not be used.

Lime

5. Hydrated lime (or lime putty) shall meet the requirements of the ASTM "Hydrated Lime for Structural Purposes," Designation C–6–34T, and shall be sampled and tested according to ASTM "Standard Methods of Sampling, etc." Designation C–50.

Sand

6. Sand shall consist of fine granular material composed of hard, strong, durable mineral particles, free from injurious amounts of saline, alkaline, organic, or other deleterious substances. The amount of deleterious substances shall not exceed 3 percent. It shall be graded uniformly from fine to coarse within the limits specified by the Engineer, and contain a sufficient quantity of finer sizes to give suitable workability.

Water

7. The water shall be clean, reasonably clear, and free from oil, acid and injurious amounts of vegetable matter, alkalies or other salts.

III DESIGN

Interior Dimensions

8. The interior dimensions shall be not less than required by AREA standard clearance diagrams for tunnels.

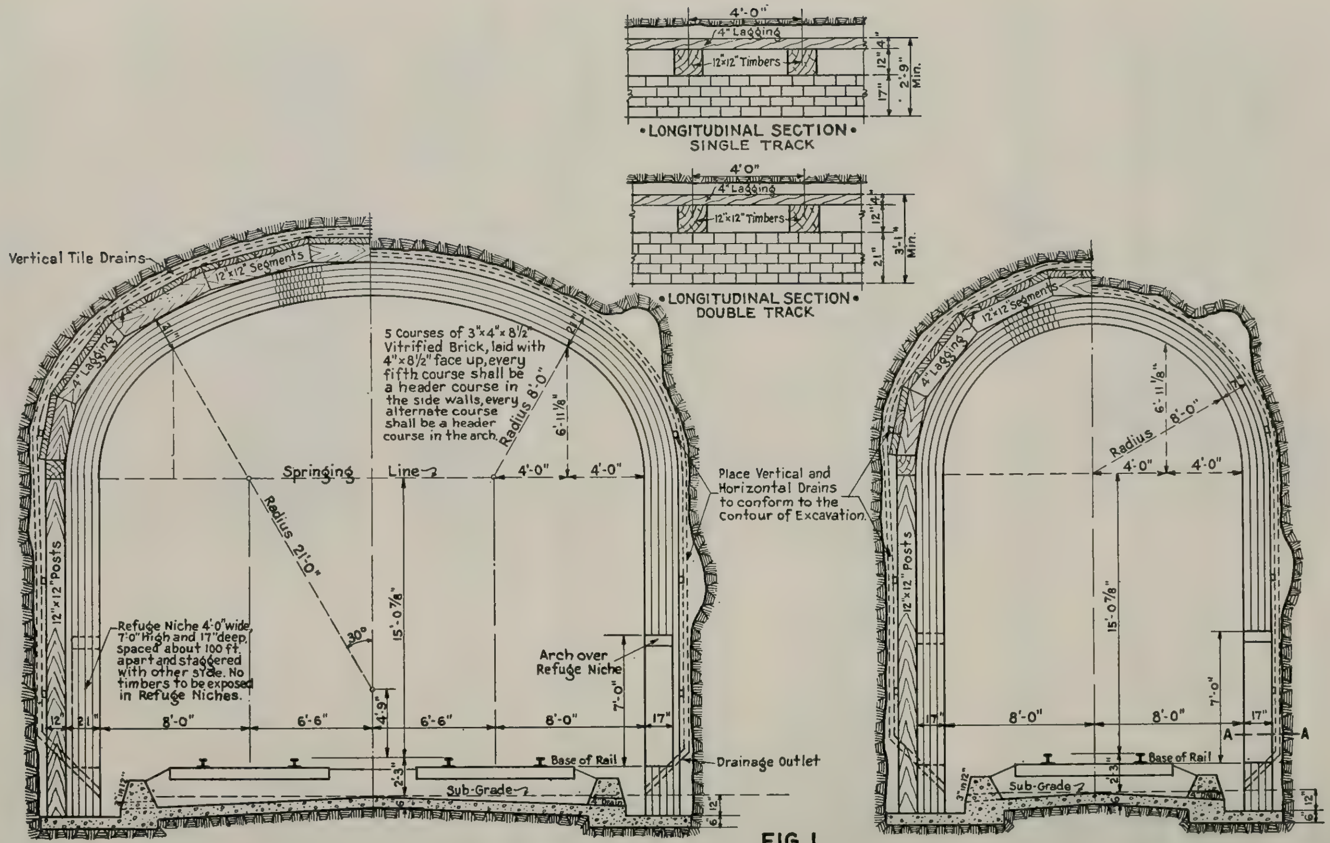


FIG. I

DOUBLE TRACK TUNNEL
BRICK LINING WITH TIMBERS

SINGLE TRACK TUNNEL
BRICK LINING WITH TIMBERS

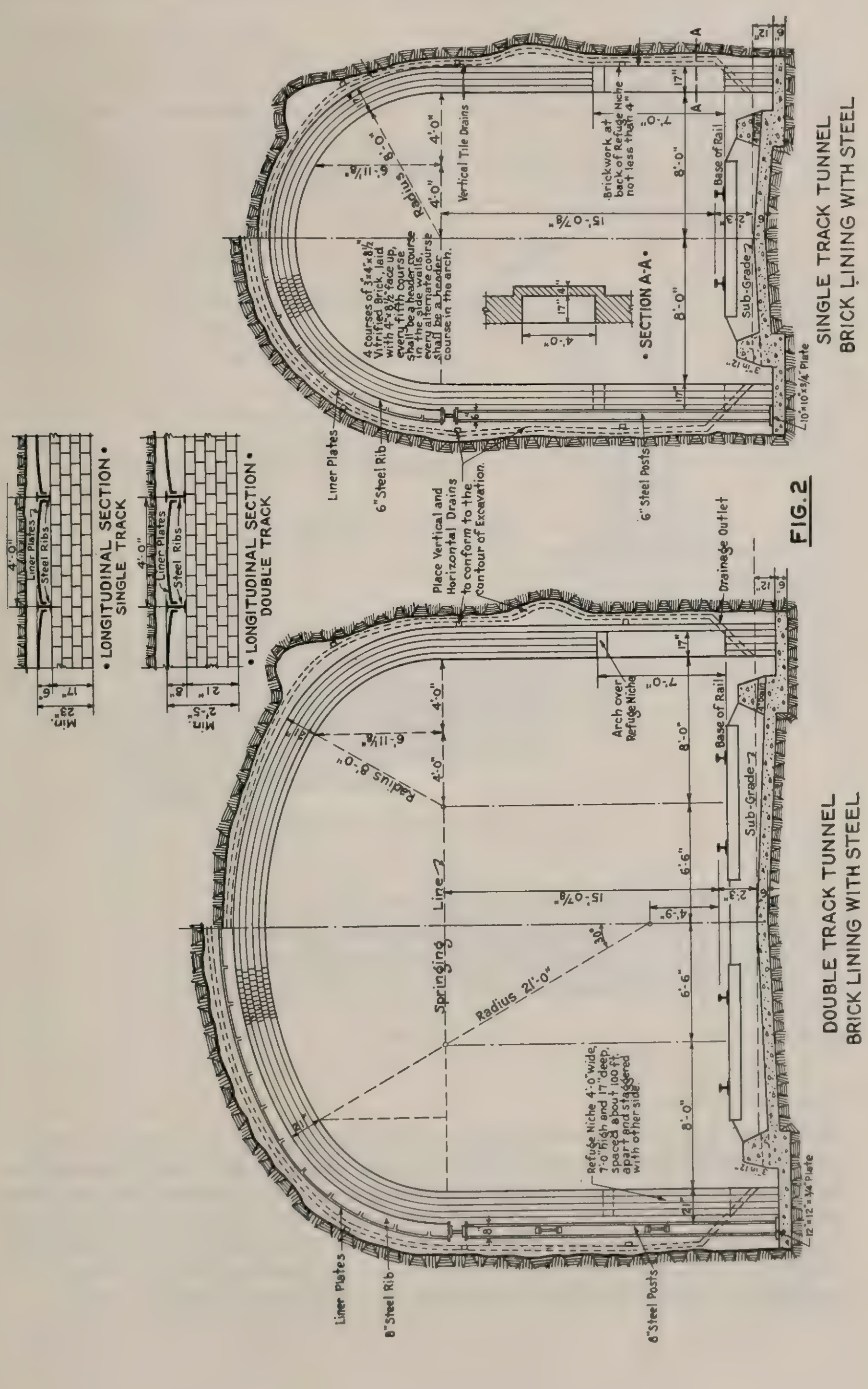
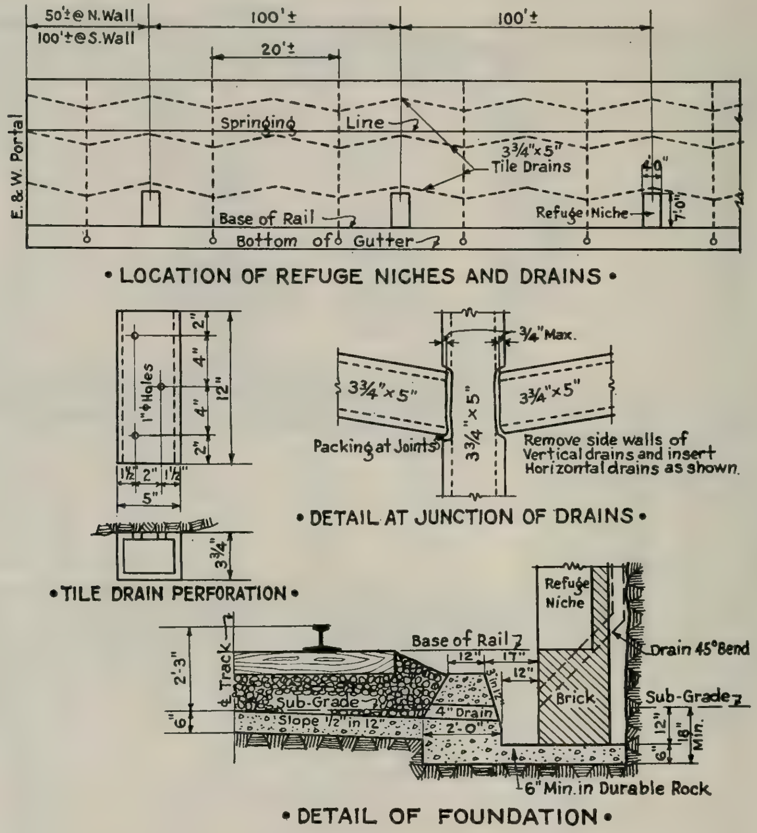

• LONGITUDINAL SECTION •
SINGLE TRACK
4'-0"
Liner Plates
Steel Ribs
9"
17"
Min. 23"
• LONGITUDINAL SECTION •
DOUBLE TRACK
4'-0"
Liner Plates
Steel Ribs
8"
21"
Min. 2'-5"
DOUBLE TRACK TUNNEL
BRICK LINING WITH STEEL
Liner Plates
8" Steel Rib
8" Steel Posts
Radius 8'-0"
6'-11 1/8"
4'-0"
4'-0"
Springing Line
Radius 21'-0"
30°
15'-0 7/8"
4'-9"
6'-6"
6'-6"
8'-0"
8'-0"
2'-3"
Refuge Niche 4'-0" wide, 7'-0" high and 17" deep, spaced about 100 ft. apart and staggered with other side.
Arch over Refuge Niche
7'-0"
17"
21"
Base of Rail
Sub-Grade
Drainage Outlet
12"
9"
3"in12"
12"x12"x3/4" Plate
Place Vertical and Horizontal Drains to conform to the Contour of Excavation.
SINGLE TRACK TUNNEL
BRICK LINING WITH STEEL
Liner Plates
6" Steel Rib
6" Steel Posts
Radius 8'-0"
6'-11 1/8"
4'-0"
4'-0"
Vertical Tile Drains
4 courses of 3 3/4"x4"x8 1/2" Vitrified Brick, laid with 4"x8 1/2" face up, every fifth course shall be a header course in the side walls, every alternate course shall be a header course in the arch.
15'-0 7/8"
8'-0"
8'-0"
17"
4'-0"
17"
4"
• SECTION A-A •
A
A
7'-0"
17"
Brickwork at back of Refuge Niche not less than 4"
Base of Rail
Sub-Grade
2'-3"
12"
9"
3"in12"
6"
L10"x10"x3/4" Plate

FIG. 2



• LOCATION OF REFUGE NICHES AND DRAINS •

• DETAIL AT JUNCTION OF DRAINS •

• TILE DRAIN PERFORATION •

• DETAIL OF FOUNDATION •

NOTE-
On double track where centers are more than 13 ft., increase distance between sidewalls accordingly. On curved track the clearances shall be increased to allow for the overhang and the tilting of a car 80 ft. long, 60 ft. between centers of trucks and 14 ft. high. The super elevation of the outer rail shall be in accordance with the recommended practice of the A.R.E.A.

Fig. 3

Floor and Ballast Walls

9. In all new tunnels, concrete floors and ballast walls shall be installed in accordance with AREA Specifications for Lining Railway Tunnels with Plain Concrete. The floor shall be at least 6 inches thick and shall slope ½ inch in 12 inches from the center line of the tunnel at the elevation of subgrade, towards the sidewalls. The ballast walls shall be 12 inches wide at the top and 24 inches wide at the floor line. The top of the walls for tangent track shall be at the elevation of the bottom of the ties. The toe of the face of the walls adjacent to the sidewalls shall be at least 12 inches therefrom.

Foundation for Side Walls

10. A concrete footing shall be provided for the brick walls. The concrete shall be made and placed in accordance with the AREA Specifications for Portland Cement Concrete, Plain and Reinforced, and shall have a minimum compressive strength of 3,000 pounds per square inch in 28 days.

The bottom of the concrete footing, in hard, durable material, shall be at least 6 inches below the bottom of the gutter. In other material it shall be carried to suitable foundation (Figs. 1, 2 and 3).

Side Wall and Arches

11. In side walls, the bricks shall be laid with their 4 inch by 8½ inch face up, and every fifth course shall be headers, in the arch, every alternate course shall be headers. Joints shall be not less than ¼ inch and not over ½ inch thick. All joints must be filled solidly with mortar.

The thickness of the sidewalls and arch shall be not less than 17 inches for single track and not less than 21 inches for double track tunnel. At intervals of approximately 20 feet, the walls shall be tied back to the natural face of the tunnel by brick spandrel walls.

The space between the natural face of the tunnel and brick lining shall be filled with concrete or hard durable stone thoroughly rammed, or tamped into place. When it is necessary to temporarily support the face of the excavation with steel or timber supports, the space between the liner plates or lagging and the face of the excavation shall be firmly packed with hard durable stone rammed into place, or sand placed pneumatically. The space between the lagging or liner plates and the brick lining shall be filled with concrete, or hard durable stone thoroughly rammed or tamped into place.

Arch centers shall be slacked—not struck—immediately after keying so that mortar may harden under slight pressure.

Drainage Openings

12. Vertical and diagonal openings, French drains, or 3¾ inches by 5 inches rectangular tile drains shall be installed as necessary in the rear of the lining, with outlets through the sidewalls to provide adequate drainage.

Weep holes shall be placed through the sidewalls at intervals of 20 feet unless drainage conditions require them placed at shorter intervals. The weep holes should be of pipe not less than 4 inches in diameter and placed on a slope of 45 degrees. The outer end of the outlets or weep holes shall be not less than 12 inches above the bottom of the gutter. Sub-drains shall be provided under the floor as necessary. Four-inch round tile drains or openings of similar area shall be installed in each 10 feet of ballast walls to provide drainage for the section of the floor between the ballast walls (Fig. 1 and 2).

Refuge Niches

13. Refuge niches shall be at least 17 inches deep, 4 feet wide and 7 feet high. In single track tunnels the brickwork at back of niches should be not less than 1 course thick. Niches should be spaced approximately 100 feet apart and staggered with opposite side so that niches will occur every 50 feet in the tunnel. The bottom of niches shall be at the elevation of base of rail.

These specifications are submitted as information with the object of presenting them later for adoption and publication in the Manual.

Appendix F

(8) Rating of Reinforced Concrete Bridges

G. E. Robinson (chairman, subcommittee), F. W. Capp, M. L. Johnson, J. E. Kalinka, C. P. Marsh, J. L. Rippey, C. P. Schantz, A. W. Smith, E. O. Sweetser.

Your committee has canvassed the railroad engineering profession on this subject over the past two years and finds a practically unanimous sentiment to the effect that each reinforced concrete bridge is an individual problem with characteristics and conditions of its own which make it inadvisable, and in the opinion of the committee impossible, to determine its capacity by hard and fast rules.

One feature which the committee would like to bring to the attention of the Association is, that very complete and comprehensive records should be kept, and filed, on each such structure throughout its construction and subsequent life.

The committee recommends that consideration of this subject be discontinued for the present.

Appendix G

(9) Progress in Cement Manufacture and Testing

C. P. Marsh (chairman, subcommittee), F. W. Capp, Maurice Coburn, W. K. Hatt, A. C. Irwin, L. M. Morris.

In considering this subject, the subcommittee thought it desirable to preface its consideration of the subjects "manufacture" and "testing" by a brief review of the progress in research investigations as to the nature of hydraulic cement, and for the sake of clarity it has deemed it best to confine this review, as regards constitution, to Portland cement which is by far the most important of all the cements used in this country.

Manufacture and Constitution

In the manufacture of Portland cement, mixtures of limestone and shale, or equivalent raw materials, are ground very fine, then burned in a rotary kiln at a temperature sufficiently high to melt part of the material. In this process the oxides which are present cannot exist in the form in which they are present in the original raw materials, but re-combine to form various other substances. In the kiln, when the maximum temperature is reached a part of the charge is present as a liquid; the solids present at this point are usually:

(a) Tricalcium silicate, $3CaO.SiO_2$ (C_3S)
(b) Dicalcium silicate, $2CaO.SiO_2$ (C_2S)
(c) Magnesia, MgO

and in some cases:

(d) Tricalcium aluminate, $3CaO.Al_2O_3$ (C_3A)
(e) Tetracalcium alumino-ferrite, $4CaO.Al_2O_3.Fe_2O_3$ (C_4AF)

As the charge cools the liquid which contains some of all the oxides present in the charge in solution, tends to crystallize and increase the quantity of the above five solids. During this cooling the composition of the liquid is changing and the percentages of the solid compounds are also changing. If the cooling is not slow enough to allow complete crystallization, a part of the liquid will be frozen and exist in the clinker as a glass.

The percentages of the solids and the composition of the glass are, therefore, dependent upon the rate and degree of cooling. They may be altered further by the presence of minor constituents, such as soda and potash.

The liquid present in the material in the kiln draws the solids into compact masses known as clinker. Portland cement is the product obtained by grinding the clinker with a small percentage of gypsum.

Investigations are under way to determine the state of combination of the minor constituents and the influence of glass. Until such investigations are completed, it is not possible to take the minor constituents into account in calculating percentages of the cement compounds from the oxide composition, or to make an accurate estimate of the influence of glass. It has been found useful, however, to calculate the percentages of the compounds on the assumption that no glass is present, and ignoring the minor constituents. A clear explanation of the method of making this calculation has been published by Bogue.[1]

Relation of Chemical Composition to Physical Characteristics

From the extensive investigations of the Portland Cement Association as reported by Gonnerman,[2] a general summary by Bogue[3] and researches by Davis, Carlson, Troxell and Kelly[4], the more important relations of the chemical composition of Portland cement to such characteristics as strength, length changes, resistance to sulphate waters, resistance to freezing and thawing and heat of hydration, of mortars and concretes made from a large number of commercial and laboratory-prepared cements of a wide range of compositions, are summarized as follows:

1. Strength

Tricalcium silicate (C_3S) is the compound chiefly responsible for high early strength, while dicalcium silicate (C_2S) contributes largely to the strength beyond 28 days. Tricalcium aluminate (C_3A) contributes to strength to an important degree only during the first 28 days. The role of tetracalcium alumino-ferrite (C_4AF) is not clearly indicated, but it contributes to some extent to strength at 28-day and later ages.

2. Contraction in Air

C_3S and C_2S contribute to approximately the same degree to the total contraction, but to a much lesser degree than C_3A and to a somewhat greater degree than C_4AF.

3. Resistance to Sulphate Solutions

Of the four major compounds, C_3A appears to be the only one which reduces the resistance to sulphate solutions. However, good resistance was obtained when the C_3A did not exceed roughly 7 to 9 percent. Decrease in C_3A showed a noticeable decrease in expansion of cylinders stored in sulphate solutions, although for a C_3A content below 7 percent the expansion was not excessive. Expansion in water also tends to decrease with decreased C_3A.

4. Resistance to Freezing and Thawing Tests

For concrete cylinder tests, the higher the total content of C_3S and C_2S, the greater the resistance, while the higher the C_3A and C_4AF content, the lower the resistance. The adverse effect of C_3A appears considerably greater than for C_4AF.

5. Effect of MgO

(a) *Strength.*—The substitution of MgO for CaO in the raw mix gives decreased strength with increase of MgO content, due mostly to change in the relative proportion of C_3S and C_2S present. The addition of MgO, with the C_3S, C_3A and C_4AF held constant, gives little change except for MgO contents of 7 percent or more, when decreased strength results.

(b) *Contraction in Air.*—Substitution of MgO for CaO gives little change in total contraction. Addition of MgO tends to reduce contraction with increase of MgO.

(c) *Expansion in Water.*—Concrete shows increased expansion with increased MgO, regardless whether MgO is added to or substituted for CaO.

(d) *Resistance to Sulphate Solutions.*—Concrete stored in sulphate solutions up to 20 months shows excessive expansion for MgO content over 5 to 7 percent.

(e) *Resistance to Freezing and Thawing.*—With increase of MgO, the resistance to freezing and thawing tends to decrease.

6. Effect of Glass Content as Related to Unsoundness

This is a new subject and the summary given must be considered quite tentative:

When glass is formed by rapid cooling of the clinker, a part of the MgO present dissolves in the liquid; hence, we find MgO in two forms, one as free MgO and the other dissolved in the glass. The data appear to show that free MgO is responsible for delayed unsoundness while if the same amount of MgO is dissolved in the glass, delayed unsoundness does not occur.

Unsoundness due to free CaO, as revealed by the steam test, is well known. Unsoundness as developed in the autoclave may be due either to free CaO or free MgO or both.

Quick cooling of clinker with consequent formation of glass has a similar effect on tricalcium aluminate (C_3A) as with MgO. For C_3A contents above 6 to 8 percent, where the clinker is cooled slowly, the autoclave expansion increases rapidly; however, if the same clinker is cooled quickly, forming glass with incident dissolving of the components of the C_3A in the glass, the expansion is slight.

7. Heat of Hydration*

(a) Chemical composition has an important effect upon both the rate and total amount of heat of hydration during any period.

(b) The compounds rank as follows, from greatest to least, in heat liberated:

C_3A—Mostly during early stages of hardening.

C_3S—Mostly during "secondary" stage of hardening. (1 to 7 days)

C_2S and C_4AF—Slow and long continued.

(c) Increased loss on ignition shows a decrease in heat of hydration.

(d) Finer grinding results in greater heat of hydration. For high C_3A content, finer grinding has greater effect at early ages than at later ones; for high C_2S content, finer grinding has somewhat less effect at early ages than at later ones.

(e) Cement containing glass shows higher heat of hydration at the later ages than the same composition without glass content; at early ages (3 days), there is little difference.

(f) While not related to cement composition, the following relations are given: Increasing the water-cement ratio a certain percentage, increases the heat of hydration approximately one-fifth of this percentage. For the same water-cement ratio and the same curing temperature, the heat of hydration is practically independent of the richness of the mix.

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* Heat of hydration as used herein means the cumulative heat of hydration generated from the time of addition of water up to any specified age.

Nature of Hydrated Cement

As information on this important subject, the "Summary" from a report of studies by Brown and Carlson,[5] is quoted in its entirety:

> As observed by microscopic examination of thin sections, set cement consists mainly of three components: calcium hydroxide crystals, calcium silicate gel, and unhydrated cores of cement grains. The gel, which is porous, appears to fill substantially all intergranular spaces not filled by the hydroxide. Thus the degree of porosity of the gel varies with the conditions under which it is developed. Coarse cement and high water content produce more porous gel than do fine cement and low water content. Correspondingly, coarse cement and high water content produce large crystals of calcium hydroxide and low strength.
>
> The strength of Portland cement is probably developed by the gel acting as a void-filling glue, rather than by any type of crystallization. Other things being equal, the less calcium hydroxide observed in a thin section, the greater the corresponding strength.
>
> Because with a given water-cement ratio and a given mix the intergranular pore space is not greatly altered in total amount by changing the nature of the cement, and because substantially all of the pore space is found to be filled either with gel or with calcium hydroxide after cement hydration, that cement which hydrates most completely should produce the densest gel and the strongest specimen. This observation seems to be in line with the facts that greater strengths are shown by (1) finer cements, (2) greater ages of hydration, (3) replacement of dicalcium silicate by tricalcium silicate (for early ages), and (4) higher curing temperatures.
>
> Steam curing, after brief preliminary storage at normal temperature, is found to produce substantially the same hydration products as are produced by prolonged curing at normal temperature, except that the gel is noticeably more dense and perhaps approaches crystallinity. When 40 percent of silica is added before steam curing, most of the calcium hydroxide disappears, probably through combination with the added silica, and the greater strength observed is attributed to the formation of more gel through this puzzolanic action.
>
> Puzzolanic materials, which contain silica capable of combining with calcium hydroxide in the presence of moisture, appear to reduce the amount of hydroxide and to increase the amount of gel in set cement. The lower hydroxide content in hardened Portland-puzzolan cements can be observed qualitatively in thin sections. The lack of hydroxide is most noticeable when the specimens space contain very active puzzolanic materials such as diatomaceous shale. Thus, the study of thin sections offers a rough but informative means of determining the effectiveness of puzzolanic materials in absorbing calicum hydroxide from hardened cements.
>
> The ability of a small quantity of very porous gel to fill relatively large intergranular spaces is illustrated in thin sections from cement containing only coarse particles. In this case the hydration is slight and the intergranular spaces are large, yet a majority of the spaces, even up to 50 or 100 microns in size, are filled with gel. The gel in such a case is shown to be very porous by the rapidity with which it is attacked by carbon dioxide, and by its ready absorption of melted resin.
>
> The moist gel of Portland cement is more readily attacked by exposure to carbon dioxide than are the calcium hydroxide crystals. The carbonation of the gel is found to leave a skeleton, supposedly silica gel, with minute calcium carbonate crystals distributed through it. The more coarsely porous the gel, the more readily it is attacked by the carbon dioxide. Dry gel appears to be immune to attack by carbon dioxide.

The gel of Portland cement contains normally (1) the oxides of calcium and silica in about the same relative percentages found in dicalcium silicate, and (2) an indefinite amount of water. The higher the temperature, the lower the water content, until at a temperature near the dissociation temperature of calcium hydroxide practically no water remains in the gel. As the dicalcium silicate contains about the same percentage of calcium as does the gel, this silicate does not hydrolyze noticeably under ordinary conditions. Not only by chemical analysis but also by examination of thin sections, the only hydration product of dicalcium silicate is found to be the calcium silicate gel. This gel has tremendous cementing power, producing in a small neat cylinder a compressive strength of 10,000 lb. per sq. in. at one year, even though the hydration at this age is probably less than one-fourth complete.

The gel produced by the hydration of dicalcium silicate is found to be similar to that resulting from the hydration of tricalcium silicate. In either case, a wide range in density and corresponding pore size may be observed, depending upon a number of factors such as temperature, age, water content, etc. At early ages of hydration, the gel of dicalcium silicate is likely to be more porous than the gel of tricalcium silicate.

No evidence is found indicating any crystallization of calcium hydroxide within the gel. The pores of the gel appear to remain open and to serve as channels of migration for the calcium hydroxide, which is liberated from the core of each cement grain only when the core is accessible to water by means of these same channels.

Progress in Manufacture

The extensive research into the constituents of Portland cement which has been carried on, has led to a better understanding of the chemical reactions taking place or desired during burning, and to a closer control of the raw mix, the burning, cooling, handling and grinding of clinker to produce the cement. The principal mechanical change has been the introduction of air separators and the general adoption of closed circuit grinding for both raw materials and burned clinker.

In closed circuit grinding the coarser materials not passed by the air separators, or in wet grinding by the slurry separators, are returned to the mills for further grinding.

As to the raw materials, the use of either the air separators or slurry separators, has eliminated to a large extent the production of particles ground to an unnecessary degree of fineness. It has also eliminated from the product fed to the kilns those particles which were too coarse to undergo the desired reactions in the burning within the time limits imposed by the kiln. The result has been a more uniform burning in the kilns and the production of a more uniform clinker.

Wet grinding of raw materials has also come into more general use. The factors leading to this are, that the materials when wet, grind more easily; a great deal of dust is eliminated; where clay or marl are used, the preliminary drying of these materials, which naturally exist in a wet or damp state, is eliminated.

The length of the kilns has been increased, the longest one in operation in the United States being 372 ft., with one 450 ft. long under construction, while in Europe a length of 500 ft. has been reached. Longer kilns are required where the materials are fed to the kilns in a wet condition than when they are fed to the kilns dry.

The use of the air separators in the grinding of the clinker has resulted in producing a more uniform product as it has resulted in the elimination, to a large degree, of those particles which are unnecessarily fine, and of those particles which are too coarse to hydrate properly.

Classes of Cement

Of recent years the need has been felt in construction work for Portland cements differing in certain respects from what would ordinarily be furnished under ASTM Standard Specifications.

There has also been a demand for cements having certain qualities which were not characteristic of Portland cement. These demands have resulted in the production in this country of a variety of new cements which, with the older cements, may be generally classified in part as follows:

1. Portland Cement
   (a) Standard
   (b) High-early strength
   (c) Low heat
   (d) Modified or moderate heat of hardening
   (e) Sulphate-resistant
2. Blended Cements
3. Natural Cements
4. Masonry Cements
5. Calcium Aluminate Cements

1. Portland Cement

Of the Portland cements, the most important as to extent of production and use is the Standard Portland cement.

(a) *Standard Portland Cement.*—Under this heading may be included all of the Portland cements not identified by a special designation. The boundaries of chemical composition and physical characteristics for Portland cements as above classified, are not fixed by very definite limits. In some cases the boundaries over-lap and some cements might properly be classed under more than one designation. Cements of different brands and from different mills differ considerably in their qualities although they all meet the requirements of the ASTM specifications.

In meeting the competition of high-early-strength cements the standard Portland cements have been changed so that they produce much higher early strength in concrete than formerly. This has been the result of raising the tricalcium silicate content, more uniform and generally finer grinding and more burning.

(b) *High-Early-Strength Portland Cement.*—High-early-strength Portland cement has been one of the principal developments of the last dozen years. It has been the result of the demands for speed in construction and in the production of manufactured units, with the consequent saving in the cost of forms and supports which the more rapid construction permitted. The higher strength is obtained by so proportioning the raw mix as to give generally some increase of tricalcium-aluminate and a considerable increase in tricalcium-silicate in the clinker with a corresponding decrease in the dicalcium-silicate, also by grinding the cement to a greater degree of fineness and better control of the entire process of manufacture.

(c) *Low Heat Portland Cement.*—Low heat Portland cement has been an important development of the last decade. It resulted from the efforts to find some way to eliminate volume change of large masses of concrete resulting from differences in thermal expansion and contraction at such projects as Boulder dam and other large dams being constructed by the U.S. government.

The lower heat of hydration has been obtained by so proportioning the chemical compounds in the raw mix as to reduce as much as possible the tricalcium-aluminate in the clinker and to reduce the tricalcium-silicate with corresponding increase in dicalcium-silicate. This is generally obtained by the addition of iron or siliceous material, or both, to the raw mix. The loss in early strength resulting from these changes is partially compensated in finer grinding of the clinker in producing the cement. The result is a cement of low early strength but with a steady and long continued gain in strength under proper curing conditions.

(d) *Modified or Moderate Heat of Hardening Portland Cement.*—This cement is a product intermediate between what may be called the normal present-day Portland cement and the low heat cement. The raw mix fed to the kilns is so proportioned as to give higher percentages of tricalcium-silicate and tricalcium-aluminate in the clinker than is present in the low heat cement but not as high as occur in the normal Portland cement clinker. There may be some difference in the iron oxide content. It is finer ground than the normal Portland cement. This cement has come into great favor where large masses of concrete are involved and where the temperature conditions are such that the use of the true low heat cement would slow up unduly the construction program. This cement has been used by the Metropolitan Water District of Southern California; Tennessee Valley Authority; U.S. Corps of Engineers in locks and dams; by the U.S. Bureau of Reclamation in Coulee dam; in the San Francisco Oakland Bay bridge, and other projects.

(e) *Sulphate-Resistant Portland Cement.*—This cement might be considered as a variety of the low heat Portland cement as the changes in the raw mix required to produce the sulphate resisting qualities are the same in character as those required for the low heat cement. It is a Portland cement made with very low tricalcium-aluminate content, brought about either by a reduction of the alumina content, an increase in the iron oxide, or both.

One development in recent years in connection with manufacture of high-early-strength Portland cement has been the use of catalyzers and dispersal agents. The American Society for Testing Materials has revised both its specifications for Portland Cement and High-Early-Strength Portland Cement to permit the addition of such agents up to one percent provided that such additions have been specifically approved by its Committee C1 on Cement.

2. Blended Cements

A blended cement has been defined as the product obtained by intimately mixing together, preferably by intergrinding, Portland cement and more than one percent of one or more admixtures (other than the material used to regulate the set of Portland cement) which are added to alter one or more properties of the cement.

The admixtures may be any of the following:

(a) Pozzolanic materials, either natural or artificial.
(b) Cementitious materials such as limes, natural cements and other calcium silicate cements.
(c) Accelerators, plasticizers, retarders and waterproofing materials.
(d) Inert non-deleterious siliceous materials.

The word "pozzuolana" or "pozzolana" is defined by Webster as "A loosely compacted siliceous rock of volcanic origin or tuff; so called from its occurrence at Pozzuoli, Italy. When ground and mixed with lime it forms a hydraulic cement. Artificial pozzuolana is made from slag, ashes, etc."

A Pozzuolanic material has been defined as a substance which, while not necessarily cementitious by itself, possesses constituents which will combine with hydrated lime at ordinary temperatures in the presence of moisture to form stable insoluble compounds of cementitious value.

While cements made of mixtures of lime and pozzolanic materials have been used for centuries past the study of mixtures of Portland cement and pozzolanic materials designated "Pozzolan-Portland" cement is a comparatively recent development.

Among the pozzolanic materials which have been used either as admixtures or ground with the clinker are:

1. Natural volcanic ash.
2. Blast furnace slag.
3. Fly ash (the finely divided ash from burning powdered coal).
4. Burnt shales.
5. Burnt clays.
6. Trass.
7. Santorin earth.
8. Italian pozzolana.
9. Diatomaceous earth.

The relative chemical activity of the various pozzolanic materials with lime has been investigated by strength tests of pastes made of mixtures of the two materials and by means of an electrical conductivity method. The various pozzolana differ considerably in their activity and in general the activity of the artificial ones is greater than the natural ones. The activity of the natural pozzolanas is often increased by burning.

The effect of additions of pozzolanic materials upon the properties of a Portland cement are greater in the case of a high lime cement than of a low lime cement. The effect is also greater where the pozzolana is ground with the cement clinker than is the case where it is mixed with the ground cement.

Finely divided pozzolanas are capable of combining chemically with the lime at a rate which depends upon the temperature and upon the character of the pozzolana; thus in the presence of pozzolana the uncombined lime is made to serve in a secondary cementing or solidifying action. This suggested the possibility that the substitution of a pozzolanic material for a part of the cement might produce a concrete of improved qualities.

To the extent that the pozzolana does not combine with the cement its fineness enables it to act as a void filler and thus reduces the space which must be filled by the silica gel of the hydrating cement and thus makes the gel denser and stronger.

Roughly, a pozzolan-Portland cement of 30 percent pozzolana and 70 percent of a high lime Portland clinker ground together, will have strength characteristics comparable with a straight low lime Portland cement.

Pozzolan-Portland cement has been used in the construction of piers for the Golden Gate bridge, piers for the San Francisco–Oakland Bay bridge and for the Bonneville Spillway dam.

These cements have been the subject of extensive investigation by Davis, Kelly, Troxell and Davis,[6] and by Davis, Carlson, Kelly and Davis.[7]

Kellerman and Runner[8] have investigated the effect of using a blend of Portland and natural cement on the physical properties of mortar and concrete.

Sand cement made by grinding intimately together Portland cement, and sand or silica rock has been known since the early nineties of the last century. For a period of time it was produced in this country by a number of factories but its use died out under the competition of the true Portland cement. In that early period it was thought that the benefit derived by grinding the Portland cement with sand was due to the cement particles being reduced to a greater fineness.

In the construction of the Arrowrock dam, Idaho, by the U.S. Reclamation Service, in 1912–13 the government engineers found that, owing to high freight costs on cement, a considerable economy could be effected by using a sand cement. In the investigations at that time it was found that the amount of colloidal (soluble) silica in the sand or crushed and ground rock used was an important factor. The theory was also advanced that the oxides of sodium and potassium if present in the sand, acted as catalytic agents in facilitating the reactions between the silica and the hydrated lime of the cement. In that work the Portland cement was reground with the sand. It seems that there is but little difference between the sand-cement of that time and what is now called pozzolana-Portland cement.

The ASTM has published a Proposed Tentative Specifications and Methods of Tests for Blended Cements.[9] Lack of space does not permit of any discussion of the great number of blended cements to which the blended materials are added for waterproofing purposes. The blended cements to which the blended materials are added to improve the troweling properties of mortar will be commented on under the heading "Masonry Cements".

3. Natural Cement

Natural cement is made by burning a natural argillaceous limestone at a low red heat (1,000 to 1,300 deg. C.) which is sufficient to drive off carbon dioxide (CO_2). The clinker will not slake to any extent and must be finely ground before it exhibits hydraulic properties. On account of variations in the quality of raw materials available for its manufacture in different localities there were always differences in the quality of the cement produced at different places.

It was first manufactured in the United States in 1824 and prior to the introduction of Portland cement it was produced in large quantities. Under the competition of Portland cement its production declined and today it is not produced in more than a dozen localities. On account of the plasticity of its mortars it has been in favor as a masonry cement in laying brick and setting stone.

The American Society for Testing Materials has issued a Standard Specifications for Natural Cement under its serial designation C10-37.

4. Masonry Cements

Under this heading your committee refers to plastic cements used in laying up stone and brick work, but finds it difficult to present any definite statements concerning these cements owing to the large number of variables involved and to differences of opinion as to what are the desirable qualities such cements should have, the relative importance of these qualities and methods of tests for rating these qualities. As illustrating these difficulties the following is presented.

In a government report[10] 41 commercial masonry cements were classified, as to their general nature, as follows:

1. Largely Portland cement	7
2. Portland cement and hydrated lime mixtures	8
3. Portland cement and natural cement mixtures	2
4. Portland cement mixed with unidentified materials	10
5. Natural cement	4
6. Large amounts of slag	6
7. Hydraulic or hydrated lime	2
8. Not identified	2
Total	41

Twenty of these cements contained water repellent additions.

The chemical composition was extremely varied as is shown by the following table which gives the highest, the lowest and the average percentage value for each compound.

	Percent Present		
Compound	*High*	*Low*	*Average*
SiO_2	38.6	7.6	21.8
Fe_2O_3	7.8	0.4	2.4
Al_2O_3	14.2	1.3	5.7
CaO	71.4	33.3	64.4
MgO	26.2	0.5	1.3
SO_3	3.7	0.2	1.7
Ignition loss	22.6	1.4	2.4
Insoluble	39.7	0.1	0.2
Free lime	51.6	0.2	0.7

These cements produced mortars that varied from very plastic to very harsh. The water retaining qualities of the mortars varied greatly. The water retaining capacity was measured by subjecting the mortar for 1 and 3-min. intervals to a suction equivalent to that of a brick of medium absorption. After 1 min. from 53 to 98 percent of the water initially present in the mortar was retained. The least amount was retained by a cement largely Portland, the greatest by a Portland cement-hydrated lime mixture.

The compressive strength of 2-in. cubes of mortar consisting of 1 part of cement to 3 parts of pit-run Ottawa sand (dry rodded volumes) with sufficient water to produce normal flow, when tested at 28 days showed an extreme range of from about 50 to 3,650 lb. per sq. in. The strengths of the 41 cements were scattered between these extreme values. Thirteen were below 300 lb. per sq. in. and 22 below 600 lb. per sq. in.

As the result of a study of the replies to a questionnaire sent to persons considered to have definite ideas as to the desired properties of masonry cements, Mr. J. C. Pearson[11] gives the following list of the properties of masonry cement mortars arranged in the order of their relative importance from the point of view of service:

1. Plasticity or workability
2. Volume change
3. Weather resistance or durability
4. Bond strength or adhesion
5. Elasticity or flexibility
6. Rate of stiffening
7. Efflorescence
8. Impermeability
9. Strength (tensile or compressive)
10. Staining, fading, etc.

Standard tests for evaluating some of these properties have not as yet been developed. Research and experiment looking toward such development are being pursued. Both the American Society for Testing Materials and the Federal Specifications Board have issued specifications for masonry cement.

5. Calcium-Aluminate Cement

This cement is sometimes referred to as high-alumina cement but we have used the term calcium-aluminate cement as being more distinctive. It is manufactured abroad and imported into this country under the name of Fondu cement. It is manufactured and sold by one company in this country under the name of Lumnite cement. It was discovered in France and in the United States independently in 1912. In France it resulted from a search for a sulphate resistant cement, while in the U.S. it resulted from a search for a quick hardening high-early-strength cement.

On account of limited sources of suitable raw materials for its production its price is high and where strength is the only consideration it cannot compete with the present-day high-early-strength Portland cement. It is finding use in heat resistant, insulating and refractory concrete. It is also finding use in corrosion resistant concrete to resist the attack of industrial solutions and wastes, flue and stack gases, malignant ground waters, sea water and sewage. It is of value for structural concrete where high early strength and resistance to freezing are desired. Special precautions in the use of this cement, particularly in curing, are necessary.

Testing Cement

The American Society for Testing Materials has had committees studying tests for the various properties of cements for many years past. Under the direction of its Committee on Cement, co-operative tests on the part of twenty or more different laboratories in the country, involving many thousands of test specimens have been carried on.

As a result of inconsistencies found in the earlier tests, a Cement Reference Laboratory, sponsored by the American Society for Testing Materials, the Portland Cement Association and the U.S. government, was established at the National Bureau of Standards, Washington, D.C., in 1929. As a result of its inspection of the testing equipment and the methods of tests at testing laboratories throughout the country, testing equipment has been calibrated and where found defective, replaced, and testing procedures have been modified so that the results of co-operative tests at different laboratories have shown more concordant results. These inspections have also disclosed weaknesses in the specifications covering testing procedure which have been corrected.

The Standard Methods of Sampling and Testing Portland Cement adopted by the ASTM, in 1904, as a part of its Specifications for Portland Cement, remained unchanged until 1930 when it was amended and made a separate document.[12] It was further revised in 1932, in which year the society published its Manual of Cement Testing[13] to supplement the "Standard Methods". Subsequent revisions have been made, the last in 1939.

Strength Tests

The tension test on standard mortar briquettes is still retained in ASTM Standard Specifications for Portland Cement;[14] in the Standard Specifications for Natural Cement[15] and as Option No. 1 of the strength requirements in the Standard Specifications for High-Early-Strength Portland Cement.[16] Option 2 of this last mentioned specification calls for a compression test on 2-in. cubes of 1:2.77 mortar of a graded sand lightly tamped in the moulds. ASTM Tentative Specifications for Masonry Cement[17] call for a compression test on 2-in. mortar cubes of 1:3 mortar of standard Ottawa sand, thumbed in the moulds. In 1916 the society issued a Tentative Specification for Compressive Strength of Portland Cement Mortars[18] using 2-in. diameter by 4-in. high cylinders. This specification was withdrawn in 1932. In 1927 the ASTM investigated the use of 2-in. cubes of neat cement of a plastic consistency, and of 2-in. diameter, 4-in. high, 1:3 mortar cylinders, as compared with the standard 1:3 mortar briquettes.

In 1928 the ASTM Cement committee reported that,[19] "The inadequacy of the present tension briquette made of any cement for indicating what will be the strength of concrete made from the same cement, shows that the committee must study other methods of test. The briquettes or small compression test pieces of fluid neat pastes have also been shown to be lacking in this respect."

The committee therefore took up this study of compression tests on 2-in. plastic mortar cubes. In 1930 it reported the result of some of the tests and in 1934 stated, "The committee feels that now sufficient work has been done to warrant the Society issuing a tentative test method covering the various details of manipulation and equipment required to make and test a 2-in. plastic mortar cube. There is a strong feeling within the committee that the time is fast approaching, if not actually here, for incorporating such test piece in the standards for Portland cement and the possible dropping from them of the tension briquette."

The committee also reported that, "The compressive strength of plastic mortar cubes is a better measure of the compressive strength of concrete than is the tensile strength of standard briquettes."

In that same year the ASTM issued its "Tentative Method of Test for Compressive Strength of Portland Cement Mortars" using a 2-in. cube of 1:2.77 cement mortar of graded Ottawa sand. These methods of test were revised by the society in 1937.[20] In 1937 the committee stated they would investigate the use of a 2-in. concrete cube containing aggregate passing a ⅜-in. and retained on a No. 4 sieve. In 1938 the committee reported that the data accumulated on this test, had proved interesting but made no suggestion for its use. It further stated that work was under way on the use of a sand having the size and proportion characteristics of the graded sand now being used in Germany for the testing of cement.

Fineness Tests

The sieve test for fineness on the 200-mesh sieve had been included in ASTM Standard Specifications for Portland Cement up to 1938 in which year it was removed from the specifications on the grounds that it was hopelessly outmoded and meaningless. The reason for this is apparent when the size of sieve openings is compared with the size of the cement particles. The specified size of the openings of the 200-mesh sieve is 74 microns and of a 350-mesh sieve, 43 microns. The cement particles passing the 200-mesh sieve (about 90 to 95 percent of the total) will range in diameter from about 1 micron to 70 microns with about 50 percent smaller than 40 microns. It is readily understood that the percentages retained on the 200-mesh sieve give no indication of the particle size distribution of the material passing the sieve.

In ASTM Specifications for High-Early-Strength Portland Cement, as revised in 1936, the society required that the fineness be determined as specific area (sq. cm. per gm.) by means of the turbidimeter (developed by Wagner), tentative methods for making this test having been adopted in 1934.[21] The fineness requirements in this specification were also removed in 1938.

The use of the turbidimeter for determining fineness was also included in the ASTM Proposed Tentative Specifications and Tests for Blended Cements[9] which failed of adoption as a tentative standard in 1937.

The use of this method for determining the specific surface of blended cements has been criticised on the grounds that the admixtures differ in opacity depending on the character of the material and also differ in opacity from the Portland cement and therefore concordant results could not be obtained where admixtures were varied. Even though the turbidimetric method of determining fineness may not be included in purchase requirements, it is widely used by producers and by certain consumers.

The Working Committee on Fineness of ASTM Committee C1 on Cement has studied the merits of the following apparatus for determining the particle size distribution of cements, particularly in the region below the No. 325 sieve:[22]

1. Turbidimeter (Wagner)
2. Turbidimeter (Univ. of Calif.)
3. Reed–Lewis burette apparatus
4. Air analyzer (Portland Cement Ass'n)
5. Air analyzer (Smidth)
6. Air analyzer (Pearson)
7. Air analyzer (Roller)
8. Hydrometer (Bouyoukos)
9. Hydrometer (Lehigh Portland Cement Co.)
10. Hydrometer (U.S. Bureau of Public Roads)
11. Microneter

The Working Committee on Fineness, believing that there is a relation between the fineness of cement and the amount of water which might separate after moulding and before initial set, has done some preliminary work on this important question of water separation or bleeding.

In testing the pozzolan-Portland cement for the Bonneville dam the specific surface has been determined by a hydrometer method.[23] The actual correct determination of the specific surface of a material is very difficult if not impossible.

The various methods of determining this property all yield approximations. Different values will be obtained using different methods. Using the same methods, careful operators can secure concordant results. The relative merits of various methods of determining the fineness of particulate materials by mechanical analysis have been discussed by Roller.[24]

Soundness

The various ASTM specifications specify the following tests for soundness.

Portland Cements and High-Early-Strength Portland Cement

Pats stored in moist closet 24 hours and then in steam over boiling water for 5 hours.

Natural Cement

Pats stored in moist closet 48 hours and then in steam over boiling water for 5 hours.

Masonry Cement

Pats stored in moist closet 24 hours and then in steam over boiling water for 5 hours.

Blended Cement (Proposed Tentative Specifications)

(a) Pats stored in moist closet 24 hours and then in steam over boiling water for 5 hours.

(b) Pats, moulded in Le Chatelier tongs, stored in moist closet 24 hours and then in steam over boiling water for 5 hours.

(c) Three 1 by 1 by 10-in. bars of neat cement, 24 hours in moist closet, 2 hours in water and then in autoclave at 295 lb. per sq. in. pressure for 3 hours.

(d) Three 1 by 1 by 10-in. bars of plastic mortar stored in moist closet for 24 hours and then in steam over boiling water for 5 hours.

In 1938, the ASTM published, as information only, a "Proposed Method of Test for Autoclave Expansion of Portland Cement"[25] and in 1939 its Cement committee recommended a tentative test for autoclave expansion for inclusion in ASTM Specifications for Portland Cement but it failed of adoption at the annual meeting. The autoclave test has been the subject of discussion at different times since 1913 and now seems to be receiving more favorable consideration than at any previous time.

In 1937 the Portland cement industry agreed to impose upon itself the guarantee that no cement would be shipped that showed over one percent expansion in the autoclave test. The autoclave test used by the cement industry, consists of subjecting neat cement bars to steam pressure in a closed vessel at 295-lb. per sq. in. (420 deg. F.) for 3 hours.

Time of Setting

The tests for time of setting using the Vicat or Gillmore needles have not been changed for many years. Realization of the fact that these tests are subject to more variation than any of the other physical tests has caused considerable work to be done in an effort to devise better methods; however, to date no better method has been developed. In 1939, the American Society for Testing Materials dropped the final setting time requirement from its specification for high-early-strength Portland cement.

Chemical Tests

Chemical analysis of unhydrated cement is generally reported in terms of the following oxides:

Silicon dioxide, SiO_2
Aluminum oxide, Al_2O_3
Ferric oxide, Fe_2O_3
Calcium oxide, CaO
Magnesium oxide, MgO
Sulphuric anhydride, SO_3
Loss on ignition

In some cases compounds of soda and potash are known to be present as well as minor quantities of manganese and titanium. As previously stated the theoretical percentages of C_3S, C_2S, C_3A and C_4AF are calculated from the oxide compositions given above.

Methods for determining the percentages of the oxides have been formulated by the American Society for Testing Materials. In the Standard Specifications for Portland Cement there are and have been for many years past the following chemical limits:

1. Loss on ignition
2. Insoluble residue
3. Sulphuric anhydride (SO_3)
4. Magnesia (MgO)

The first of these is intended to throw out cement damaged by dampness. The second is intended to prevent adulteration or additions to the finished cement. Calcium sulphate is added to cement to control its set and the maximum on SO_3 is intended to limit the addition, as it is considered undesirable to have any more present in the cement than is necessary for that purpose. The MgO is limited as it is thought to produce unsoundness under certain conditions if present in larger quantities.

Other Tests

In the proposed ASTM Tentative Specifications for Blended Cements[9] the society has included additional tests, if required by the purchaser, for "Sulphate Resistance" and "Heat of Hydration". For masonry cements, other tests are specified, such as tests for staining, water retention and water repellency.

Comparison of Specifications

The Federal Specifications Board has issued specifications for five different types of cement: Portland, high-early-strength, moderate heat, sulphate resisting and pozzolana Portland. In addition to the usual chemical limitations, the following constituents were made subject to limitation in some or all of these specifications: Alumina, iron, silica, lime, ratio of alumina to iron, and tricalcium aluminate. The relative amounts of these compounds or constituents are what determines the type of the cement.

As a matter of general information your committee gives in tabular form a comparison of various cement specification requirements.

Bibliography

1. Bogue, R. H., Calculations of Compounds in Portland Cement, Industrial and Engineering Chemistry; (Anal. Ed.) Vol. 1, Oct. 15, 1929, p. 192. Rock Products Vol. 32, Nov. 9, 1929, p. 47.
2. Gonnerman, H. F., Study of Cement Composition in Relation to Strength, Length Changes, Resistance to Sulphate Waters and to Freezing and Thawing of Mortars and Concrete; Proceedings ASTM, Vol. 34, 1934, Part II, pp. 244–295.
3. Bogue, R. H., Constitution of Portland Cement Clinker, Paper No. 38, Portland Cement Association Fellowship, 1938.
4. Davis, Raymond E.; Carlson, R. W.; Troxell, G. E. and Kelly, J. W., Cement Investigations for the Hoover Dam. Proceedings of the American Concrete Inst., Vol. 29, 1933, pp. 413–431.
5. Brown, L. S. and Carlson, R. W., Petrographic Studies of Hydrated Cements, Proceedings ASTM, Vol. 36, Part II, 1936, pp. 332–350.
6. Davis, Raymond E., Kelly, J. W., Troxell, G. E. and Davis, Harmer E., Properties of Mortars and Concretes Containing Portland Pozzolan Cements; Jour. Am. Concrete Inst., Vol. 7, (Proc. 32) p. 80, Sept.-Oct. 1935.
7. Davis, Raymond E., Carlson, Roy W., Kelly, J. W. and Davis, Harmer E., Properties of Cements and Concretes Containing Fly Ash; Jour. Am. Concrete Inst., Vol. 33, p. 577.
8. Kellerman, W. F. and Runner, D. G., The Effect of Using a Blend of Portland and Natural Cement on Physical Properties of Mortar and Concrete; Proceedings, ASTM, Vol. 38, 1938, Part II, p. 329.
9. Proposed Tentative Specifications and Methods of Test for Blended Cements; Proceedings ASTM, Vol. 37, 1937, Part I, p. 291, and Vol. 38, 1938, Part I, p. 254.
10. Rogers, Jesse S. and Blame, Raymond L., Investigation of Commercial Masonry Cements, Research Paper No. RP 746; U.S. Bureau of Standards Journal of Research, Vol. 13, No. 6, Dec. 1934, pp. 811 to 849.
11. Pearson, J. C., Properties and Problems of Masonry Cements, Jour. Am. Concrete Inst., Vol. 28, 1932, p. 349.
12. Standard Methods of Testing Cement, ASTM Designation C77–30, 1930 Book of St'ds., Part II, p. 30.
13. Manual of Cement Testing, Proceedings ASTM, Vol. 32, 1932, Part I, p. 316.
14. Standard Specifications for Portland Cement, ASTM Designation C9–38, 1938 Book of St'ds Suppl., p. 95.
15. Standard Specifications for Natural Cement, ASTM Designation C10–37, 1937 Book of St'ds Suppl., p. 52.
16. Standard Specifications for High-Early-Strength Portland Cement, ASTM Designation C74–38, 1938 Book of St'ds Suppl., p. 97.
17. Tentative Specifications for Masonry Cement, ASTM Designation C91–38T. Proceedings Vol. 38, 1938, Part I, p. 731.

COMPARISON OF VARIOUS CEMENT SPECIFICATION REQUIREMENTS

KIND OF CEMENT	CHEMICAL REQUIREMENTS, PER CENT													FINENESS		SOUNDNESS		TIME OF SET				TENSILE STRENGTH, LB. PER SQ. INCH 1:3 STANDARD SAND MORTAR (MIN.)				COMPRESSIVE STRENGTH, LB. PER SQ. INCH (MIN.)								HEAT OF HYDRATION CALORIES PER GRAM (MAX.)		STAINING TEST, % SOLUBLE "ALKALI" (MAX.)	WATER RETENTION % OF ORIGINAL FLOW AFTER SUCTION FOR 60 SECONDS (MIN.)	WATER REPELLENCY, RATIO OF ONE HOUR ABSORPTION TO 24 HOUR ABSORPTION (MAX.)
																		INITIAL, MINUTES, (MIN.)		FINAL, HOURS, (MAX.)						2" CUBES						2"D.X 4"LONG CYLINDERS						
																										1:2.75 GRADED SAND MORTAR				1:3 STANDARD SAND MORTAR		1:3 STANDARD SAND MORTAR						
	LOSS ON IGNITION (MAX.)	INSOLUBLE RESIDUE (MAX.)	SO_3 (MAX.)	MgO (MAX.)	Al_2O_3 (MAX.)	Fe_2O_3 (MAX.)	SiO_2 (MIN.)	CaO (MAX.)	RATIO Al_2O_3/Fe_2O_3	$3CaO \cdot SiO_2$ (MAX.)	$2CaO \cdot SiO_2$ (MAX.)	$3CaO \cdot Al_2O_3$ (MAX.)	$4CaO \cdot Al_2O_3 \cdot Fe_2O_3$ (MAX.)	SPECIFIC SURFACE, SQ.CM. PER GRAM, BY TURBIDIMETER	PER CENT RETAINED ON NO. 200 SIEVE (MAX.)	BY STEAM TEST	BY AIR AND WATER TEST FOR 28 DAYS	VICAT	GILLMORE	VICAT	GILLMORE	1 DAY	3 DAY	7 DAY	28 DAY	1 DAY	3 DAY	7 DAY	28 DAY	7 DAY	28 DAY	7 DAY	28 DAY	7 DAY	28 DAY			
1938 A.S.T.M. PORTLAND C9-38	4.00	0.85	2.00	5.00												YES		45	60	10	10			275	350													
1939 A.S.T.M. HIGH EARLY STRENGTH PORTLAND C74-39	4.00	0.85	2.50	5.00												YES		45	60			275	375		①	② 1300	② 3000		①									
FEDERAL PORTLAND SS-C-191a (1936)	3.00	0.75	2.00	5.00	7.50	6.00						15.00		1500 (MIN.)		YES			60		10		175	275	350		900	1800	3000									
FEDERAL HIGH EARLY STRENGTH PORTLAND SS-C-201 (1936)	3.00	0.75	2.50	5.00	7.50	6.00						15.00		1900 (MIN.)		YES			60		10	275	375	425		1250	2500	3500										
FEDERAL MODERATE HEAT OF HARDENING PORTLAND SS-C-206 (1936)	3.00	0.75	2.00	5.00	6.00	6.00	21.00		0.7 TO 2.0			8.00		1800 (MIN.)		YES			60		10		125	250	325		750	1500	2500					70	80			
FEDERAL SULPHATE-RESISTING PORTLAND SS-C-211 (1936)	3.00	0.75	1.75	4.00	4.00	4.00	24.00		0.7 TO 2.0			5.00		1800 (MIN.)		YES			60		10			175	300			1000	2200									
BOULDER DAM LOW HEAT PORTLAND SPEC. NO.566 (1934)	3.00	0.85	2.00	5.00					2/3 (MIN.)	40.00	65.00	7.00	20.00	1700 TO 2300		YES			60		10											1000	2000	65	75			
FEDERAL POZZOLANA PORTLAND SS-C-208 (1938)	7.00		2.00	5.00			26.00	58.00								YES			60		10							1800	3000									
A.S.T.M. MASONRY CEMENT C91-38T (1938)																YES			60		48									350	600						65	
FEDERAL MASONRY CEMENT SS-C-181b ③ (1938) TYPE 1															12		YES		60		48									250	500					0.03④	65	⑤ 0.90
FEDERAL MASONRY CEMENT SS-C-181b ③ (1938) TYPE 2															12		YES		60		24									500	1000					0.03④	65	⑤ 0.90
A.S.T.M. NATURAL CEMENT C10-37 (1937)															15	YES		10	20	10	10			⑥ 75	⑥ 150													

① 28-DAY STRENGTH SHALL BE HIGHER THAN 3-DAY STRENGTH.

② MIX 1:2.77.

③ MASONRY CEMENT, FEDERAL SPECN.:
TYPE 1-FOR USE WHERE NOT EXPOSED TO FROST ACTION.
TYPE 2-FOR GENERAL USE.

④ TO APPLY WHEN CEMENT IS SPECIFIED TO BE NON-STAINING TO LIMESTONE.

⑤ TO APPLY TO WATER-REPELLENT CEMENTS ONLY.

⑥ MIX 1:2.

GENERAL NOTES ON RELATIVE STRENGTHS AT VARIOUS AGES:

SS-C-208 (POZZOLANA): 28-DAY STRENGTH SHALL BE AT LEAST 20 PER CENT HIGHER THAN 7-DAY STRENGTH.

BOULDER DAM (LOW HEAT): 28-DAY STRENGTH SHALL BE AT LEAST 35 PER CENT HIGHER THAN 7-DAY STRENGTH.

OTHER SPECIFICATIONS, IN GENERAL, REQUIRE STRENGTHS AT LATER AGES TO BE HIGHER THAN STRENGTHS AT EARLIER AGES.

18. Tentative Specifications and Tests for Compressive Strengths for Portland Cement Mortars, ASTM Book of Tentative Standards, 1930, p. 164.
19. Proceedings ASTM, Vol. 28, 1928, Part I, p. 235, 2nd para.
20. Tentative Method of Test for Compressive Strength of Portland Cement Mortars, ASTM Designation C109-37T, Proceedings, Vol. 37, 1937, Part I, p. 726.
21. Tentative Method of Test for Fineness of Portland Cement by Means of the Turbidimeter, Proceedings ASTM, Vol. 35, 1935, Part I, p. 777.
22. Report of Working Committee on Fineness, Proceedings ASTM, Vol. 34, 1934, Part I, p. 317.
23. A Hydrometer Method for Determining the Fineness of Portland-Pozzolan Cements, Proceedings ASTM, Vol. 36, 1936, Part II, p. 310.
24. Roller, Paul S., A Classification of Methods of Mechanical Analysis of Particulate Particles, Proceedings ASTM, Vol. 37, 1937, Part II, p. 675.
25. Proposed Method of Test for Autoclave Expansion of Portland Cement, Proceedings ASTM, Vol. 38, 1938, Part I, p. 297.

Appendix H

(10) Specifications for Concrete Culvert Pipe

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SPECIFICATIONS FOR THE PLACEMENT OF CONCRETE CULVERT PIPE

1. Scope

These specifications cover the placement of concrete culvert pipe for railway culverts.

2. Bedding

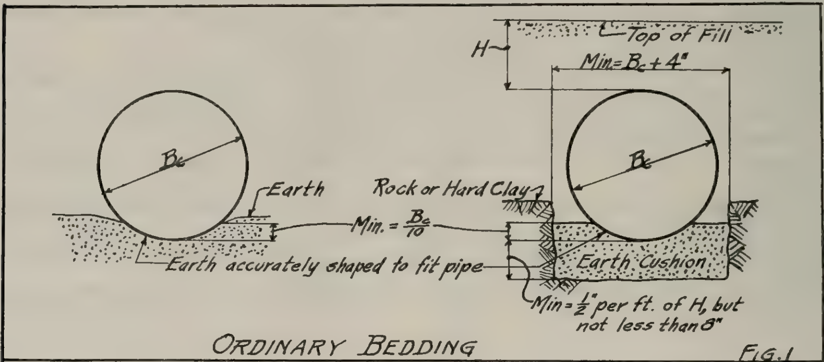
The pipe shall be placed on a cushion of earth or other finely granular material, or on a cast-in place concrete cradle, as illustrated in Figs. 1, 2, and 3. The surface on which the pipe rests shall be so shaped that the reaction will be distributed as nearly uniformly as possible over a horizontal width of not less than six-tenths of the outside diameter and all possibility of concentration of the reaction at or near the vertical diameter eliminated. If pipe having a projecting bell is used, the surface on which the pipe rests shall be shaped to fit the bell, as well as the barrel of the pipe. The acceptable methods of bedding are illustrated in Figs. 1, 2, and 3, and the Engineer shall specify which method is to be used, depending on the superimposed load and the strength of the pipe.

3. Foundation and Camber

(a) If the material under the bedding cushion or cradle is sufficiently firm to maintain the culvert on the established line and grade, cambering of the pipe line will not be required.

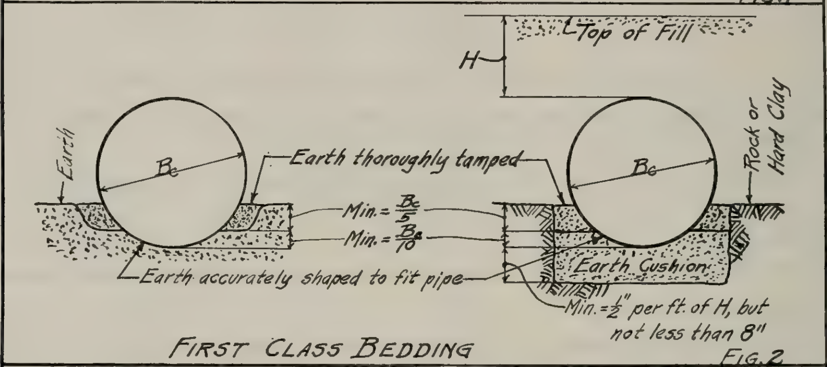
(b) If the foundation is such that it may be expected to yield a limited amount, which can be estimated with reasonable accuracy, the culvert shall be placed with sufficient camber to ensure that it will not have a sag at the end of the settlement. The camber shall be constructed by laying approximately one-half of the length of the culvert at the upstream end horizontally, or on a grade equal to about half of the average grade of the culvert, and the remainder on a sufficient grade downstream to provide the necessary camber or additional grade required. No section of pipe shall be placed higher than the one at the upstream end.

(c) If the foundation is soft or spongy, an adequate support shall be supplied by excavating the unstable soil and backfilling with firm material, by laying a timber mat



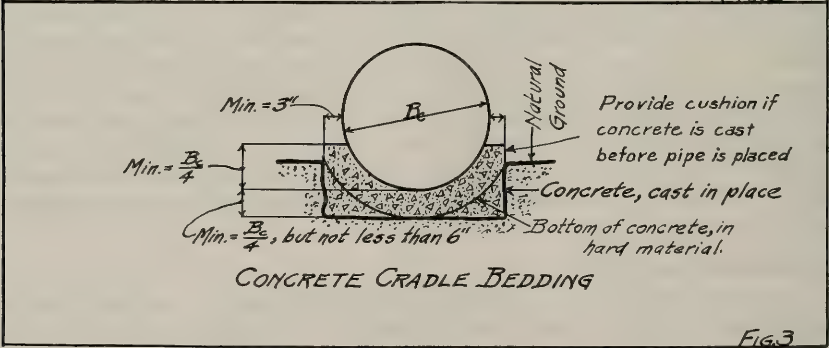
ORDINARY BEDDING

FIG. 1



FIRST CLASS BEDDING

FIG. 2


Min.=3"
B_c
Natural Ground
Provide cushion if concrete is cast before pipe is placed
Min.=$\frac{B_c}{4}$
Concrete, cast in place
Min.=$\frac{B_c}{4}$, but not less than 6"
Bottom of concrete, in hard material.

CONCRETE CRADLE BEDDING

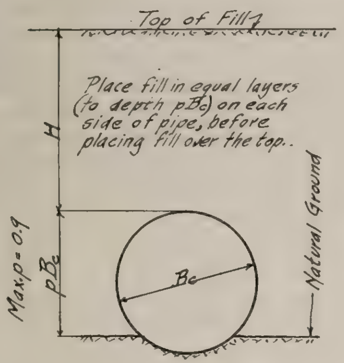
FIG. 3

on the unstable soil, or by such other means as may be specified or approved by the Engineer.

(d) If the foundation is muck, or similarly yielding material, the pipe shall be bedded above a continuous platform supported on piling, or by such other means as may be specified or approved by the Engineer.

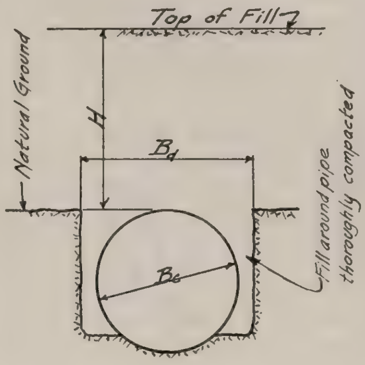
4. Backfill and Embankment

The filling around and over the culvert shall be placed in accordance with one or more of the methods outlined in Figs. 4 to 9, inclusive, as specified by the Engineer. The filling shall in all cases be placed alternately on each side of the culvert, in approxi-


Top of Fill
Place fill in equal layers (to depth pBc) on each side of pipe, before placing fill over the top..
H
Max. p = 0.9
pBc
Bc
Natural Ground

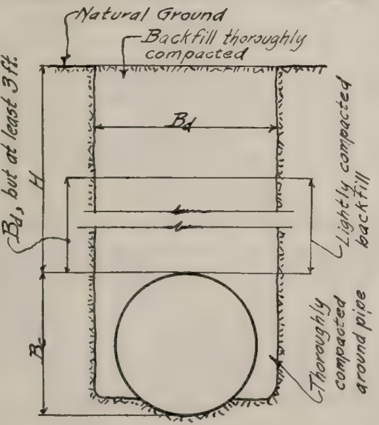
POSITIVE PROJECTION CONDITION

FIG. 4



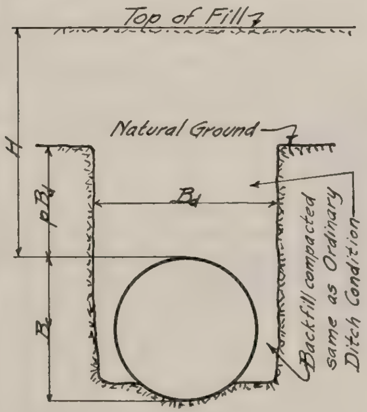
ZERO PROJECTION CONDITION

FIG. 5


Natural Ground
Backfill thoroughly compacted
Bd, but at least 3 ft.
H
Bd
Lightly compacted backfill
Bc
Thoroughly compacted around pipe

ORDINARY DITCH CONDITION

FIG. 6



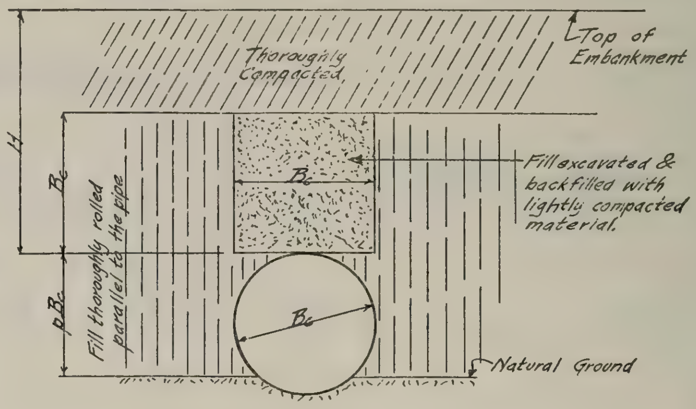
NEGATIVE PROJECTION CONDITION

FIG. 7

mately equal layers, and necessary care shall be taken to avoid displacing the pipe. Rock fill shall not be dumped over the culvert without a sufficient cushion of earth to prevent breakage.

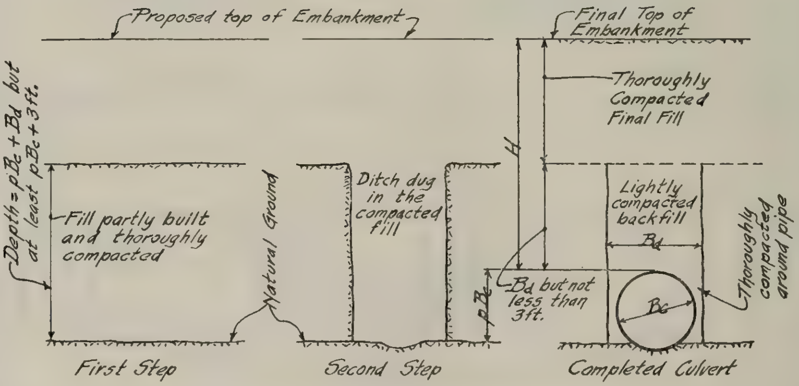
5. Jacking Pipe Through Fills

Pipe used for jacking through fills shall be without projecting bells. The tongue shall preferably be at the downstream end. A ring of tarred or bitumen-coated rope shall be placed around the tongue of each pipe section at the joints, to prevent the entrance of water during construction and to form an annular space for sealing with mortar from the inside after the jacking has been completed.


Top of Embankment
Thoroughly Compacted
H
B_c
Fill thoroughly rolled parallel to the pipe
Fill excavated & backfilled with lightly compacted material.
B_c
pB_c
B_c
Natural Ground

MODIFIED DITCH CONDITION

FIG. 8


Proposed top of Embankment
Final Top of Embankment
Thoroughly Compacted Final Fill
Depth = $pB_c + B_d$ but at least pB_c + 3 ft.
Fill partly built and thoroughly compacted
Natural Ground
Ditch dug in the compacted fill
H
Lightly compacted backfill
B_d
pB_c
B_d but not less than 3ft.
B_c
Thoroughly compacted around pipe
First Step
Second Step
Completed Culvert

ALTERNATE MODIFIED DITCH CONDITION

FIG. 9

Jacking frames shall be so constructed as to avoid breaking the pipe or forcing it out of alinement. The pipe shall preferably be jacked upgrade to provide drainage at the heading during excavation. Satisfactory means shall be provided for maintaining the lead pipe in the correct grade and direction. If the line shows signs of developing excessive resistance to movement, jacking shall be carried on continuously until the jacking of the entire culvert has been completed.

6. Constructing Culverts in Tunnel

When it is necessary to place pipe culverts by tunneling, plans shall be prepared for the construction procedure and timbering.

7. Joints

(a) Bell and spigot pipe shall preferably be bedded with the bell end upstream. The interior surface of the bell shall be thoroughly cleaned and wetted, and the lower portion filled with a stiff mortar of sufficient thickness to make the inner surfaces of the abutting sections flush. The spigot end of the next section shall also be cleaned and wetted, and fitted into the bell so that the sections are closely matched. The annular space in the bell shall then be filled with mortar and the inner surface of the pipe brushed smooth at the joint.

(b) Tongue and groove pipe shall preferably be laid with the groove upstream. A shallow excavation shall be made underneath the pipe at the joint, and filled with stiff mortar into which the next section of pipe is laid. The groove end of the first pipe shall be cleaned and wetted, and a layer of mortar applied to the lower half of the groove. The tongue end of the next section shall also be cleaned and wetted, and a layer of mortar applied to the upper half of the tongue. The tongue shall then be fitted into the groove and shoved in place so that part of the mortar is squeezed out, and the sections closely matched. The inner surface shall then be brushed smooth at the joint.

(c) Joints in pipe that is jacked in place shall not be sealed with mortar until the jacking of the culvert has been completed.

This report is presented as information.

Appendix I

(12) Pressure Grouting

W. M. Ray (chairman, subcommittee), Maurice Coburn, G. F. Eberly, O. V. Parsons, I. L. Pyle, G. E. Robinson, G. R. Smiley, C. H. Splitstone, F. W. Capp.

The practice of pressure grouting is becoming more general year by year due chiefly to the variety of its application. If the scope of this practice may be judged by the engineering literature on the subject, its applications are indicated by a standard bibliography listing some 200 descriptive articles in the following proportions:

	Percent
1. To dams and reservoirs	25
2. To shafts and tunnels	28
3. To other structures	23
4. To soil and foundation treatments	24
Total	100

Typical practice of the United States government and other agencies as to consolidation of dam foundations and reservoir basins is described in two articles as follows:

Grouting, by J. P. Growdon, chief hydraulic engineer, Aluminum Company of America. Review of Lectures and Discussions Ohio River Division, Concrete School, Pittsburgh Engineer district, U. S. Corps of Engineers, January, 1935.

Text and Discussions

Grouting Dam Foundations and Construction Joints; Calderwood Dam on Little Tennessee River, by James B. Hays, Engineer, Hydraulic Department, Aluminum Company of America, Pittsburgh. Civil Engineering, November, 1933.

The extent of the Calderwood Dam work is indicated by the fact that in grouting this dam foundation 1,227 sacks of cement were used in 2,942 lin. ft. of 30-ft. holes at 50-lb. pressure and 4,684 sacks in 5,407 lin. ft. of 100 to 200-ft. deep holes at 600-lb. pressure.

Recent reports and specifications on flood control work under the U. S. district engineer at Pittsburgh, Pa., use some special terms with reference to grouting jobs as follows:

In locations where the overburden has been cleared off or a trench excavated to uncover foundation or reservoir area to be grouted, it is found advantageous to lay down a course of concrete in which are inserted pipes through which test holes are later drilled to various depths. These pipes carry fittings to which connections for grouting are later made. The purpose of the cap is to seal the surface so that pressure may be applied to the substrata through the drilled holes.

Under certain conditions, as at the heel of a dam or under the footing of a cut-off wall, a continuous line of grout holes is located. This operation is termed curtain wall grouting and, in such cases, the footing of the cut-off wall, or the heel of the masonry dam itself may serve as the grout cap. The procedure in such work may be generally outlined as follows:

(a) Sub-surface conditions are developed by drilling test holes to locate seams and crevices in the foundation rock. An examination of the cores will show how deep the grout curtain must be carried to prevent leakage. The proposed hydrostatic pressure must also be taken into account. A dam 250 ft. high must be protected by a deeper grout curtain than a dam 50 ft. high. In any case a section of the foundation along the upstream edge of the dam and extending beyond the ends of the dam must be made completely impervious. This will generally require that Portland cement grout must be forced into the cracks and crevices of the rock under a pressure not less than three times the anticipated hydrostatic pressure.

(b) The relative spacing and depths of holes and pressures used in grouting should be adjusted to meet local conditions in each case. Percussion drills have been found satisfactory for vertical holes up to a depth of 50 ft. to 60 ft. Diamond core drills are preferred for greater depths or where holes are to be drilled at angles to intersect existing rock seams as nearly as possible at right angles.

(c) A typical description of procedure for curtain wall grouting is quoted from specifications for Mahoning dam issued by the U. S. district engineer office, Pittsburgh, as follows:

> (1) Drill and grout the first series of holes in the area under construction on 20-ft. centers.
>
> (2) After the first series of holes in any area has been grouted and the grout has set up, drill and grout a second series of holes midway between the holes of the first series.
>
> (3) After the second series of holes has been grouted, and the grout has set up, drill and grout a third series of holes midway between the holes completed in the first and second series.
>
> (4) If, in the opinion of the contracting officer, any hole in the third series takes an excessive amount of grout, the grouting shall be stopped, and after the grout has set up, intermediate holes shall be drilled and grouted on each side of it. This process shall be repeated if the contracting officer considers it necessary.
>
> Cleaning and Protection.—After a hole has been completely drilled, it shall be thoroughly washed out with clean water under continuous pressure in a manner which will permit free outflow, by inserting a small pipe and directing the wash water against the wall of the hole. When the washing of each hole has been completed it shall be immediately grouted or be protected from becoming clogged or obstructed

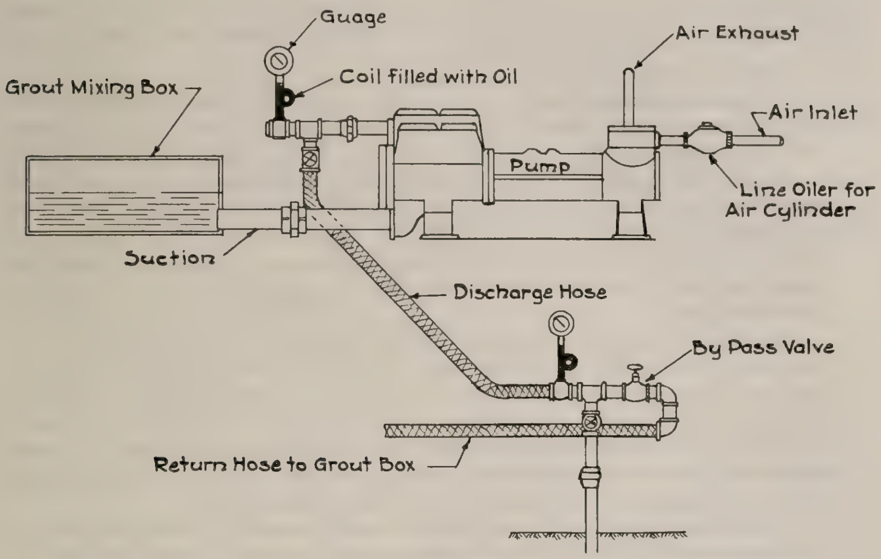


FIG. 1

by being temporarily capped, or otherwise suitably protected, and any hole that becomes obstructed shall be opened up to the satisfaction of the contracting officer, by and at the expense of the contractor. The contractor shall include the cost of washing out holes and temporary capping in his contract price for drilling the holes.

Equipment to be used.—Grout shall be injected by means of duplex piston displacement pumps capable of delivering cement grout continuously at mixes varying from practically clear water to a mix of 3 parts cement to 2 parts of water by volume and at pressures of at least 100 lb. per sq. in. in the hole. The pumps shall be served by a high speed mechanical mixer and shall pump from a sump containing an effective mechanical agitator. The pipe line connecting to the hole shall be equipped with an accurate pressure gage at the hole. A return line from the hole to the mixing tank shall be provided and equipped with such regulating devices that the speed of the pump may remain constant even though the rate of grout consumption varies. (See Fig. 1).

Grouting of Railroad Structures

Recent application of pressure grouting practice to railroad structures is illustrated by two jobs as follows:

(1) Tunnels

See article on Tunnel Lining Surgery by Lawrence A. Luther (Compressed Air Magazine, March 1938) being an account of extensive repairs to the lining of a tunnel on the Atchison, Topeka & Santa Fe through a spur of the coast range at Franklin Canyon about 30 miles east of San Francisco, Cal. In amplification of this article, Mr. M. C. Blanchard, chief engineer, Santa Fe Coast Lines has kindly furnished this committee, under date of Nov. 18, 1938, with a complete description of the restored tunnel lining as effected in 1937–38, from which the following statements are quoted:

> Length of tunnel—5,600 ft.
>
> Construction started May, 1898, completed July, 1899, lined with timber but on account of frequent failure or movement of the arch support posts, the tunnel was not opened to traffic until July, 1900, and it was April, 1901, before final retimbering was completed. During the timbering, continual trouble was encountered because of the pressure of "swelling earth" and the occurrence of slides, caving and gas pockets. In relining operations additional excavation was necessary on walls, roof and floor to maintain the required cross section and a re-designed lining also failed. This process was repeated until some sections had been enlarged and retimbered two to six times.
>
> Experimental sections were lined with concrete in the main tunnel and in a right angle drift which also failed, and a complete replacement of the timber lining with concrete was decided upon. This work was started September, 1907, and progressed intermittently until October, 1910. The tunnel as rebuilt had a semicircular arched roof 15.6 ft. in diameter at the spring line, which was 12.7 ft. above top of rail, and width of 14.1 to 14.5 ft. at top of rail. The track on crushed rock ballast was supported on a concrete floor with a center drain.
>
> Progressive failure of the tunnel lining became evident in recent years. Due to pervious materials on each side of the divide, 1,500 ft. at the east end and 1,000 ft. at the west end have been wet, which condition in combination with the effects of locomotive fumes made repairs and reinforcement necessary.
>
> The repair program as adopted, involved (1) the solidifying and waterproofing of the existing lining by pressure grouting, (2) the rebuilding of the spalled areas by the pressure-gun method and, (3) the fumeproofing and waterproofing of the entire surface of the concrete. The method consisted of forcing a cementing, void-filling material that solidified quickly into the honey-combed and cracked concrete. Therefore, where this method was used, it was not necessary to remove the entire mass and the work could be done at a comparatively small cost and at a considerable reduction in the time required to do the work and in delays to train operation.
>
> The material used in the pressure grouting consisted of a special hydraulic concrete containing Portland cement and an hydraulic active filling material. When mixed in a plastic state it was readily forced into porous concrete so as to completely fill the voids, and set into a hard dense concrete that was thoroughly bonded in place. It did not separate or plug during the grouting process, and was without shrinkage. The volume of water used in the mix and the proportions of the ingredients were determined by conditions at the time and place of application. The quantity of grouting material used per cubic yard of defective concrete restored averaged 6.2 cu. ft. Observations of test cylinders and core specimens indicated that the lining in those portions of the tunnel that had been repaired by this process developed a strength of not less than 5,000 lb. per sq. in. in 30 days.
>
> In repairing the surface failures in the concrete, as evidenced by spalling and cracks, conventional practice was followed in chipping out the defective material, using pneumatic hammers, and in placing and anchoring reinforcing steel. These cavities were then filled with the same material used in the grouting process, which was applied by the pressure gun method. After the structural repairs had been completed, the surface of the concrete in the arch was fumeproofed by first sandblasting it and then by applying the fumeproofing material under a pressure of 80 lb. per sq. in. This material was applied by means of pneumatic grinders espe-

cially fitted with tubing in such a manner that the sealing material reached the surface of the concrete through the arbors of the carborundum surfacing wheels used. Thus, simultaneously with its application, the material was worked into the surface of the concrete, and since it had sufficient body to fill the surface voids and was highly resistant to blast action and fumes, its application resulted in a dense and durable "case hardening" of the concrete. In the repaired portions of the tunnel practically no water seepage had occurred since the work was completed.

Equipment.—Ten standard-gage scaffold cars were used, each a complete operating unit moved by a self-propelled track mounted air compressor serving also to operate pneumatic tools and equipment. In general, two of these cars were assigned to each of five operations, viz:—

1. Drilling and chipping.
2. Placement of reinforcement.
3. Pressure application of concrete.
4. Grouting.
5. Water and fumeproofing.

Grouting Eqiupment.—In the grouting process the material was pumped into the concrete by an air-operated plunger-type pump having a discharge capacity of 35 gal. per min. and capable of exerting a maximum nozzle pressure of 465 lb. per sq. in., discharge taking place through a 1-in. high-pressure hose. Two tanks for mixing the materials were provided on each car. While one tank was being pumped, the other was being mixed, so that the pumping operation could be carried on continuously, the opening of one feed valve and the closing of another being all that was necessary to switch from the empty to the full tank. The capacity of the feed or mixing tanks (60 gal.) was such that approximately the same time was required for mixing in one while the other was being emptied during the pumping operation. Each mixing tank was provided with mixing and agitation blades propelled by an air motor, which were in continuous motion during either the pumping or mixing operation.

Approximately two to four gallons of water were required for each cubic foot of grout materials, the proportion of water to materials varying with the density of the mass to be solidified. In all cases, however, the mix was made as dense and as stiff as could readily be forced into the voids to be filled. This density or stiffness was determined in advance by forcing water through previously drilled holes in the concrete and observing the pressure and volume of water which could be taken. This being known, the operator in charge, through experience and training, could determine the desirable consistency and water content of the grouting materials for the area in question. Mobility of the equipment permitted its prompt transfer from the tunnel to clear on sidings at each end of the tunnel, requiring about 15 min. to clear main track.

Work done by contract under the supervision of G. W. Harris, chief engineer, Santa Fe System; M. C. Blanchard, chief engineer, Coast Lines; F. D. Kinnie, district engineer; and Roger Goode, resident engineer.

(2) Consolidation of Foundations

Arresting subsidence of a concrete roadway ramp structure at the Chesapeake & Ohio station, at Charleston, W. Va., is reported in Bulletin 301 of the Dravo Corporation, Pittsburgh, Pa., from which the following data are selected:

> An outstanding example of the successful use of the cementation process for the consolidation of loose surface deposits is found in this work. The ramp is carried

on an abutment and nine pairs of pillars on 50-ft. centers. The foundation of each pillar is 9 ft. square and extends 10 ft. below the surface designed to take a maximum load of 4,000 lb. per sq. ft. Immediately after completion it was found that subsidence was taking place under dead weight alone. The footings rested on filled material down to bed rock at a depth between 40 and 50 ft. As the ground was porous and in order to retain the grout within the footing area it was found necessary to inject a barrier of sand from holes spaced around each pier after which cement was injected through hollow drill rods and the ground thoroughly consolidated and hardened, with only a comparatively small loss of grout in the surrounding ground.

On completion of the cementation work, the job was tested by loading the ramp with sand for its full length, producing a total load on the foundations of 4,600 lb. per sq. ft. No further subsidence resulted and the structure was then opened to traffic.

This was quite an extensive undertaking involving 562 injection holes with a total footage of 19,000 lin. ft. and involving the injection of 14,000 sacks of cement.

Grouting With Chemicals

Special materials for grouting are discussed in a recent periodical[1] that included the following statements:

Synopsis.—Abroad, consolidation of soils by chemicals, usually sodium silicate in combination with calcium chloride or some heavy metal salt, is practiced extensively. Early difficulties in controlling time of set have been overcome. The two chemicals are now injected simultaneously instead of separately. Chemical grouting is particularly useful in soils too fine for other types of grout to penetrate.

The consolidation of ground by grouting has undergone many changes in practice. The old terms of grout and grouting have ceased to mean specifically a liquid mixture of cement and water and the process of injecting it into soils and rock to make them watertight and strong. All sorts of water mixtures of clay, bentonite, asphalt and chemicals make up the grouts now used in ground solidification for engineering works. In this article grouts of chemicals are considered. These have increased in use remarkably in Europe but not greatly in the United States.

Permeability is greater.—Chemical grouting makes its chief claim on its greater ability of penetration; it will penetrate finer-grained soils and smaller seams in rock. Solids suspended in water can penetrate no opening smaller than their particle sizes. Indeed, according to the theory of filters, a material of grains ten times larger than those in suspension will keep back practically all of the suspended grains. Since cement grains have a diameter of 0.004 in., sand with grain size of 0.04 in. would stop cement grout.

Then follows description of "How Chemicals Act, Development of Processes and Examples of Practice."

(3) Unit Masonry Structures

These include arches, piers and walls which show indication of stress and incipient failure due to deterioration of mortar joints and probably inferior backing. Such conditions may be due to leaching out of inferior mortars or gradual breaking up because of impact or settlement.

Such structures should be carefully explored by drilling or otherwise to develop actual conditions which may indicate that pressure grouting is inadvisable, and that grout should be applied by gravity or with low pressures under close control. Where fairly large masses of masonry are involved, observation drill holes may be kept open to check the flow and distribution of the grout, and the final results of such grouting may be definitely established by properly located test drilling after the grouting is completed and set.

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[1] Engineering News Record August 17, 1939—Page 61.

(4) Foundation Caissons

Foundation caissons sunk by the pneumatic process, which have been concreted by depositing and distributing concrete under air pressure, may be tested for voids under the roof of the working chamber and completely filled by pressure grouting through properly placed drill holes.

(5) Other Applications

The use of grout to consolidate and render impervious materials surrounding shafts, foundation excavations, tunnels, etc., has a wide field but its successful application requires careful planning and execution by persons having special experience.

Negative Results

A negative decision in the matter of grouting for the purpose of consolidating an area of East River bottom as struck by a New York City sewer tunnel is described in Engineering News-Record of August 5, 1937, as follows:

> All idea of attempting to drive through the disintegrated region at the 300 ft. level was abandoned after the supplementary borings revealed the true nature of the material. Two distinct zones of bad ground were revealed, one about 35 ft. wide near the Manhattan heading, another zone 115 ft. wide at the island side. There appeared to be no possibility of grouting this material, especially in two of the contact planes. The fluid occupying these joints was found in places to consist of exceedingly fine chlorite particles (mainly of hornblende) much finer than commercial cement. It was not believed advisable to try to displace this very fine mud with actually coarser injected cement; it probably could not be done as the mud would probably have penetrated the cement, and made the formation of any solid and water-tight area around the tunnel practically impossible.

Materials.—For most purposes grout consists of finely ground Portland cement and water. The cement should pass a No. 200 sieve, as coarse particles may prevent the desired penetration. Where porous material or cavities are encountered, sand may be added to make a mortar. Asphaltic and other compounds, some of which are patented or privately controlled are promoted for use in special cases. The use of preparatory clean out application of water or chemicals in drill holes is sometimes detrimental.

Special attention is being given to the condition of railroad masonry structures on most of the principal railway lines of the country as many of such structures have apparently reached an age and are operating under conditions of loading, etc., such as to develop signs of distress and disintegration. A recent editorial on this subject[2] reads in part as follows:

> Among outstanding monuments to early railway construction engineers that still remain throughout many sections of the country, are the bridge abutments, piers and arches constructed of cut stone masonry; in most cases these are carrying loads and withstanding impacts far in excess of any that might have been reasonably foreseen by their builders.

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[2] Railway Engineering and Maintenance. August, 1939—Page 463.

> The weakness of many of these old structures, even of those ranked as among the most outstanding, has been due most frequently to the distintegration of the lime or natural cement mortar used in their construction. When this disintegration has been evident from the surface it has usually been remedied by repointing. However, only in recent years has much attention been given to the interior of these structures, where deterioration of the old mortar, if there ever was any mortar, has frequently extended to the point where the interior appears to be a mass of rubble or spalls with no binder within itself or between it and the face stones. Where this condition has been found, interiors have been solidified and bonded with the facia courses by internal grouting, either under pressure or by gravity. In fact this procedure has been so advanced in recent years, frequently involving the use of non-shrink grouts to insure compactness and the exclusion of moisture, that the repaired structures are as strong or stronger and more durable than the original structures.
>
> This is a class of repair that should not be overlooked, because it is entirely possible for masonry structures to appear much stronger than they actually are. In any case, the solidifying of old masonry acts to prolong greatly the service life of these structures at only a fraction of the expense of replacement.

More recently in the American Railway Bridge and Building Association this matter was given special attention by an address delivered by J. F. Leonard[3] before that body reading in part as follows:

> Masonry is not a real monolith, but rather is composed of two parts—the dimension stone and the mortar. Even if the stone has remained in good condition, the mortar often breaks down. Furthermore, masonry structures are elastic, and the constant repetition of strains tends to break down and cause working at the joints between the stone and mortar. Another source of our trouble today is the common construction practice of earlier years of using dimension stone for the face only. In the case of arches and walls (and I think of bridge abutments as walls), rubble stone, with or without mortar, was used for backing, and in the case of piers, the core was sometimes of rubble and sometimes of spalls. As a result the core provided a place for water to collect, with an endless cycle of freezing and thawing in cold climates.
>
> We have now, however, many very old masonry structures where the mortar is pretty well shot, but where there has never been any mortar replacement except pointing, which after all is only at the face of the joint. With the mortar gone, the sharp high points in the stones get into contact, causing knife-edge bearing, and then the stone cracks. The only method I know of to restore this mortar and thus again produce a monolith for your masonry is by pressure grouting. This is accomplished by drilling holes in the masonry and injecting cement grout under pressure. This grout can be all the way from neat cement to one part of cement to three parts of sand, and fine, sharp engine sand is best. The neat cement grout will penetrate into smaller openings, and has the further advantage of being able to use a direct acting pump for the projection. Where a large amount of grout is needed, pneumatic apparatus is generally adopted, as it permits the mixing of sand with the cement. In some cases for both methods, an admixture is used as a waterproofing agent, or to obtain better penetration, or both. Personally, for stone arch consolidation, I much prefer the direct acting pump method, as giving you complete control

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[3] J. F. Leonard, engineer bridges and buildings, Central Region, Pennsylvania Railroad, Pittsburgh, Pa.

at the point of the deposit. In our treatment of old arches, we first generally drill our holes all the way through the stone and try to deposit a layer of grout at low pressure back of the stone against the earth fill, to consolidate the backing and build up a waterproof envelope. After this has been permitted to set, it also serves to pump against in our next attempt to fill all of the mortar joints and cracks in the stone. Further, since we cannot see what has gone on inside during all these years, it also serves to consolidate and restore any badly weathered dimension stone. In addition to the hole used to place the grout, numerous other holes should have been bored for the successive grouting, and they serve in the meantime to act as observation points to observe the progress of the grout. After the backing is deposited, then the grout holes should only penetrate part way. Finally the grout will begin to run out at the joints in the stone, and these are then plugged with oakum or waste, as are the adjoining drill holes where found necessary.

In some cases the arch stones themselves have become badly weathered on their faces, deep spalls have fallen out, and the entire structure has become weak. Where failure has progressed this far, various methods of lining have been attempted. The oldest and most common practice has been to build forms under the arch and to deposit a new ring of concrete about two feet thick, cutting a shoulder for it to rest on, or setting it on one of the old footing offsets. More recently, steel liner plates, instead of wood forms, have been used in arch strengthening work and have the advantage of considerable arch strength in themselves. Where these plates are used, the backing is generally of grout. Most recently, substantially reinforced shotcrete has been used as a lining. By "substantially reinforced shotcrete" I mean a balanced design to produce real strength.

What has been said with regard to masonry arches applies equally well to retaining walls, abutments and stone-lined tunnels, except that any extraneous lining is not needed or should be handled in a different fashion. In the case of tunnels, the problem is much more complicated than in the case of simple arches. For pier masonry, in general, the problem of solidification, so far as the shaft is concerned, is essentially one of straight pressure grouting.

Many difficulties have, of course, developed in the behavior of footings and their supports. Each one of these is a particular problem in itself. There has, however, been considerable progress in the consolidation of footings and foundations by means of pressure grouting.

In a recent monograph the Portland Cement Association discusses restoration of old stone masonry by pressure grouting[4] in part as follows:

Restoring Old Masonry by Pressure Grouting discusses grouting old stone masonry structures of two types: (a) those with earth on one side, as retaining walls, abutments and solid spandrel arches; (b) piers and open spandrel arches.

Grout.—Neat grout will not flow freely into holes smaller than about three times cement particle, which based on 200-mesh sieve of .0028 in. opening would be a .0084 hole. These limitations also apply to other finely pulverized materials and sand. (See Grouting With Chemicals, Eng. News Record 8/17/39).

Sand.—Except in large cavities where mortar or concrete can be placed, all sand should pass 28-mesh sieve and have large portion passing 50 and 100-mesh sieves. Mason's engine and beach sands are usually satisfactory. Mix may vary from neat grout to about a 1:1 mix.

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[4] Concrete for railways—Vol. 3, No. 2.

Water.—It is best to put 50 percent of water into mixer before the dry ingredients and add remaining water. Continuous supply of grout better than an intermittent one. It is best to start with definite volume of mixing water and 1 bag cement. For grouting old masonry it should not be necessary to use more than 10 or 12 gal. water per sack. Grouts with as little as 4½ gal. per sack have been handled.

Holes.—In general 1½-in. diam., usually normal to face, but for footings may be drilled at 45 deg. or other angle. In some cases vertical holes from top to bottom of wall or pier even through foundation are advisable, pump through small pipe in holes, pipe withdrawn as grouting progresses.

Pressure.—Greater than 25 lb. to 50 lb. rarely needed, and in excess of 100 lb. very rarely. Hand mixing is approved for this work.—See Civil Engineer May 1939 and November 1933 (Hays).

Apparatus.—A grouting machine generally consists of a small mixer, which discharges into a receiver which is air tight when closed, and is emptied by compressed air through a discharge pipe or hose to the capped drill hole or other point of application. Otherwise the grout or mortar is drawn into the cylinder of a reciprocating pump and propelled directly into the discharge pipe. For ordinary quantities and conditions a hand pump is often sufficient as the operation can be fully controlled and pressures up to 100 lb. per sq. in. can be applied. A rotary pump has recently been developed for grouting which is giving satisfactory service. Sketch of Grout Pump hook-up as used by U. S. Engineers at Tygart River Reservoir Dam is attached as a typical installation operated by compressed air. (See Fig. 1.)

Pressure.—The pressures required will vary widely with the conditions of application. For ordinary structural repairs and drill holes from 30 to 50 feet in depth, pressures from 50 to 100 lb. per sq. in. will generally be found sufficient. For deep holes and grouting joints, in some Government dams pressures from 600 to 2,500 lb. per sq. in. have been used.

In conclusion it should be stated that new materials and new methods for grouting will continue to be used and developed and that each job requires a careful study to secure the best results, rather than the unthinking use of grouting procedure which has been followed elsewhere.

Reference is also made to Section 2 of report of subcommittee No. 3, Committee 8, Page 641 of AREA Proceedings for 1936, entitled "Grouting and its Application to Masonry."

This report is presented as information.

Report of Committee 15—Iron and Steel Structures

R. A. Van Ness, *Chairman,*
James Aston
F. E. Bates
J. E. Bernhardt
R. N. Brodie
A. W. Carpenter
C. H. Chapin
O. F. Dalstrom
R. P. Davis
Herbert Ensz
W. G. Grove
G. A. Haggander
Shortridge Hardesty
C. S. Heritage
O. E. Hovey
Jonathan Jones
A. R. Ketterson
A. M. Knowles
P. G. Lang, Jr.*
B. R. Leffler
H. S. Loeffler
F. M. Masters
C. H. Mercer
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F. J. Pitcher
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C. E. Sloan
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G. L. Staley
H. C. Tammen
G. H. Tinker
G. H. Trout
F. E. Turneaure
F. P. Turner
C. E. Webb
E. Weidemann
H. T. Welty
A. R. Wilson
W. M. Wilson
Committee.

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* Died December 9, 1939.

To the American Railway Engineering Association:

Your committee respectfully reports on the following subjects:

1. Revision of Manual (Appendix A).

2. Specifications for fusion welding and gas cutting for steel structures, collaborating with ASTM Committee A-1 on Steel, and the American Welding Society Conference Committee on Bridges. No report.

3. Non-ballast type of solid deck steel bridges. Progress in study—no report.

4. Design of expansion joints involving iron and steel structures. Progress in study—no report.

5. Design of connections in which rivets develop tension. The report on this assignment appeared in Bulletin 412, page 81, "Design of Connection Angles for Stringers of Railway Bridges, By W. M. Wilson, Research Professor of Structural Engineering, University of Illinois". Complete and presented as information.

6. Review specifications for overhead highway bridges of the American Association of State Highway Officials in so far as they relate to steel construction, conferring with that association. No report.

7. Progress in design of steel bridge details (Appendix B). Complete and presented as information.

Philip George Lang, Jr.

Philip George Lang, Jr., engineer of bridges, Baltimore & Ohio, and a member of Committee 15 for 16 years, died at his home in Baltimore on December 9, 1939.

Born in 1883, and a graduate of the University of Pennsylvania in 1905, Mr. Lang occupied an active place in bridge engineering throughout his entire professional career, in all but two years of which he was identified with the Baltimore & Ohio. Because of his broad experience, during the course of which he had an important part in the design and building of large and important structures, he proved an exceptionally valuable member of Committee 15. His interest, in more recent years, in the application of fusion welding to structural steel, served further to increase his usefulness to the committee and led to his elevation to the presidency of the American Welding Society.

The members of the committee deeply feel the loss occasioned by his death.

The Committee on Iron and Steel Structures,
R. A. Van Ness, *Chairman.*

Bulletin 415, January, 1940.

Appendix A

(1) Revision of Manual

O. E. Selby (chairman, subcommittee), F. E. Bates, R. N. Brodie, O. F. Dalstrom, H. Ensz, C. S. Heritage, O. E. Hovey, A. R. Ketterson, A. M. Knowles, H. S. Loeffler, F. M. Masters, O. K. Peck, I. L. Simmons, S. M. Smith, H. C. Tammen, G. H. Trout, F. E. Turneaure, C. E. Webb.

The following definition is recommended for adoption and publication in the Glossary:

—Angle of Skew.—The angular deviation of one of two intersecting lines from a right angle to the other. *15*

The following revisions of the Specifications for Steel Railway Bridges are recommended:

206 p. 15–6

Change the third line and the next sentence to read:

(a) The rolling effect:

The rolling effect is due to the rolling of the live load from side to side.

209 p. 15–8

Change the last item of the first paragraph to read:

(c) For viaduct towers and bents, the vertical projections of all columns and tower bracing.

212 p. 15–8

Revise to read:

Nosing of Locomotives

212. The lateral force to provide for the effect of the nosing of locomotives (in addition to the other lateral forces specified) shall be a single moving force of 20,000 pounds applied at the top of the rail, in either lateral direction, at any point of the span. The resulting vertical forces shall be disregarded.

305 p. 15–11

Revise to read:

305. Web members shall be so proportioned that an increase in the specified live load that will increase the total unit stress in the chords at the center of the span by one-third will produce total unit stresses in the web members not in excess of one and one-third times the specified designing stresses. Members and their connections subject to reversal of stress under such increased live load shall be proportioned in accordance with Art. 215 (Reversal of Stress), using the increased designing unit stresses.

411 p. 15–13

Change number to 421 and revise to read:

421. In pin-connected riveted tension members the net section beyond the pin hole, parallel with the axis of the member, shall be not less than the required net section of the member. The net section through the pin hole, transverse to the axis of the member, shall be at least 40 percent greater than the required net section of the member. The ratio of the net width (through the pin hole transverse to the axis of the member) to the thickness of the segment shall not be more than 8.

Renumber intermediate articles.

419 p. 15–14

Change the second paragraph to read:

If rivets carrying stress pass through fillers, the fillers shall be extended beyond the connected member and the extension secured by enough rivets to distribute the total stress in the member uniformly over the combined sections of the member and the fillers.

423 p. 15–15

Add "of Compression Members" to the caption and insert "of compression members" after "ends" in the first line.

504 p. 15–20

Revise to read:

504. Holes may be punched full-size in material used for lateral, longitudinal, or sway bracing, lacing, stay plates, and diaphragms, if the material is not more than ⅞ inch thick.

Holes in main material forming a part composed of not more than 3 thicknesses may be punched full-size if no thickness is more than ⅝ inch. If there are more than 3 thicknesses of main material, or if any thickness is more than ⅝ inch, the holes in all of the thicknesses shall be punched-and-reamed, except that if any thickness is more than the nominal diameter of the rivets minus ⅛ inch, the holes in that thickness shall be drilled.

When reaming of the flanges of plate girders is required, the holes in the connected legs of the end stiffeners and in the fillers under the stiffeners shall be reamed.

516 p. 15–21

Change the first sentence to read:

516. Rivet heads shall conform to the requirements of the American Standards Association, American Standard, Large Rivets, ½ inch Nominal Diameter and Larger, designated ASA B–18.4—1937. See page 15–134 of the Manual.

523 p. 15–22

Revise to read:

523. Sheared edges of plates of main material more than ⅝ inch thick shall be planed to a depth of ¼ inch. Web plates and pin plates (regardless of thickness) of pin connected tension members shall be universal mill plates or shall have edges planed ¼ inch and the ends back of pins planed ¼ inch.

523a p. 15–22

Omit the last sentence.

523b p. 15–22

Insert a new article with the caption "Re-entrant Cuts" to read:

523b. Re-entrant cuts shall be filleted.

701 p. 15–25

Replace the first sentence with the following:

701. The payment in pound-price contracts shall be based on the weight of the metal in the fabricated structure, including field rivets shipped. Either scale weights or computed weights may be used at the option of the fabricating contractor.

703 p. 15–26

Revise the second paragraph to read:

The weights of the heads of shop driven rivets, in accordance with the following table, shall be included in the computed weight:

Diameter of rivet, inches	½	⅝	¾	⅞	1	1⅛	1¼
Weight of 100 heads, pounds	4	7	12	18	26	36	48

Part 2 p. 15–27

In the reference to ASTM specifications at the head of Part 2, change A7–34 to A7–36.

Alloy Steels p. 15–45

Insert as paragraph 9 of the foreword:

9. On account of the possibility of fatigue failure, the allowable unit stresses in Article 1601 shall not apply to members that will be subjected to a large number of stress cycles during the life of the bridge and having either reversal of stress or low dead load stress. For such members the allowable unit stresses shall be reduced, and in floor systems shall not exceed those specified in Article 301.

Change number of present paragraph 9 to 10.

1601 p. 15–46

Change the introductory clause to read:

1601. Except as limited in Paragraph 9 of the Foreword, the allowable unit stresses to be used in proportioning the parts of a bridge shall be as follows:

1601 p. 15–46

In the formula for compression members, pin ends, nickel steel, change the factor 0.90 to 0.86.

1610 p. 15–48

Change to read:

1610. Sheared edges of alloy steel shall be planed to a depth of ¼ inch. Flame-cut edges shall be machined or else chipped and ground to a depth of ¼ inch.

Appendix A. p. 15–48.1

For all of the page after Formula (2), substitute the following:

For compression members with known eccentricity of loading, for all slenderness ratios, the formulas are:

For riveted ends.
$$p = \frac{\dfrac{y}{f}}{1 + \left(\dfrac{e_1c_1}{r_1^2} + 0.25\right) \text{Sec.}\, \dfrac{0.75l}{2r_1} \sqrt{\dfrac{fp}{E}} + \dfrac{e_2c_2}{r_2^2} \text{Sec.}\, \dfrac{0.75l}{2r_2} \sqrt{\dfrac{fp}{E}}} \qquad (3)$$

For pin ends.
$$p = \frac{\dfrac{y}{f}}{1 + \left(\dfrac{e_1c_1}{r_1^2} + 0.25\right) \text{Sec.}\, \dfrac{0.875l}{2r_1} \sqrt{\dfrac{fp}{E}} + \dfrac{e_2c_2}{r_2^2} \text{Sec.}\, \dfrac{0.875l}{2r_2} \sqrt{\dfrac{fp}{E}}} \qquad (4)$$

p = allowable average compressive unit stress.
e_1 = known eccentricity of the applied load in the direction of the smaller value of r (r_1).
e_2 = known eccentricity of the applied load in the direction of the greater value of r (r_2).

c_1 = distance from neutral axis to extreme fiber in the direction of r_1.
c_2 = distance from neutral axis to extreme fiber in the direction of r_2.
l = length of member.
$r = r_1$ = least radius of gyration of the member.
r_2 = radius of gyration of the member in a direction at right angles with that of r_1.
Values of e, c, l, and r are in inches.
E = modulus of elasticity = 29,400,000.
y = yield point in tension:
33,000 for structural steel.
45,000 for silicon steel.
55,000 for nickel steel.

From the parabolic formulas in Articles 301 and 1601, for $\frac{l}{r} = 0$

$$\begin{aligned} p &= 15{,}000 \text{ for structural steel} \\ &= 20{,}000 \text{ for silicon steel} \\ &= 24{,}000 \text{ for nickel steel} \end{aligned}$$

From formulas (1) and (2), for $\frac{l}{r} = 0$

$$p = \frac{y}{f} \div 1.25 \text{ from which } f = \frac{y}{1.25p}$$

Using the foregoing values of y and p, the following values of f are derived:

1.76 for structural steel
1.80 for silicon steel
1.83⅓ for nickel steel

The coefficient 0.25 in the denominators of the formulas provides for inherent crookedness and unknown eccentricity.

The following revisions of the Rules for Rating Existing Iron and Steel Bridges are recommended:

108 p. 15–123

Change "lurching" to "rolling" in line (b) (second line on page) and in the caption and first line of paragraph (b).

In 3. under (c) Hammer Blow Effect:

For formula (a) substitute,

$$H = \frac{100}{2pf}\left(\beta f^2 - 0.1 \frac{D - D_u}{D} \frac{f^2}{f^2 - n_s^2} \right)$$

For formula (b) substitute,

$$H = \frac{100}{2pf}\left(\beta N^2 - 0.1 \frac{D - D_u}{D} \frac{f^2}{f^2 - n_s^2} \right)$$

108 p. 15–124

Insert the following after the definition of "D":

D_u = central deflection of the span, in inches, when loaded with the train, tender, and unsprung weight of the locomotive.

Change definition of D_h to read:

D_h = maximum central deflection of the span, in inches, due to the hammer blow of the locomotive drivers at 1 r.p.s., acting statically.

Insert after the definition of "n",

$n_1 = \sqrt{\frac{12}{d + D_u}}$ = the frequency of the span, vibrations per second, under the train, tender, and unsprung weight of the locomotive.

Change the equation for "*f*" to read,

$f = \frac{n_1}{n}\sqrt{n^2 + 5}$ = the second or higher critical frequency resulting from locomotive spring action.

110 p. 15–125

Change the last item of the first paragraph to read:

(c) For viaduct towers and bents, the vertical projections of all columns and tower bracing.

111 p. 15–125

Change to read:

111. Nosing of Locomotives

The lateral force to provide for the effect of the nosing of locomotives shall be a system of moving forces equal to $\frac{1}{16}$ of the axle loads on the span applied at the top of the rail in either lateral direction. The resulting vertical forces shall be disregarded. The number of axle loads shall not exceed those of one locomotive without the tender.

115 p. 15–127

For the paragraph beginning "Stresses in plate girders" substitute the following:

Plate girders, I-beams, and other members subject to bending that produces tension on one face, shall be computed by the moment-of-inertia method. The neutral axis shall be taken along the center of gravity of the gross section. The tensile stress shall be computed from the moment of inertia of the entire net section and the compressive stress from the moment of inertia of the entire gross section.

Appendix B

(7) Progress in Design of Steel Bridge Details

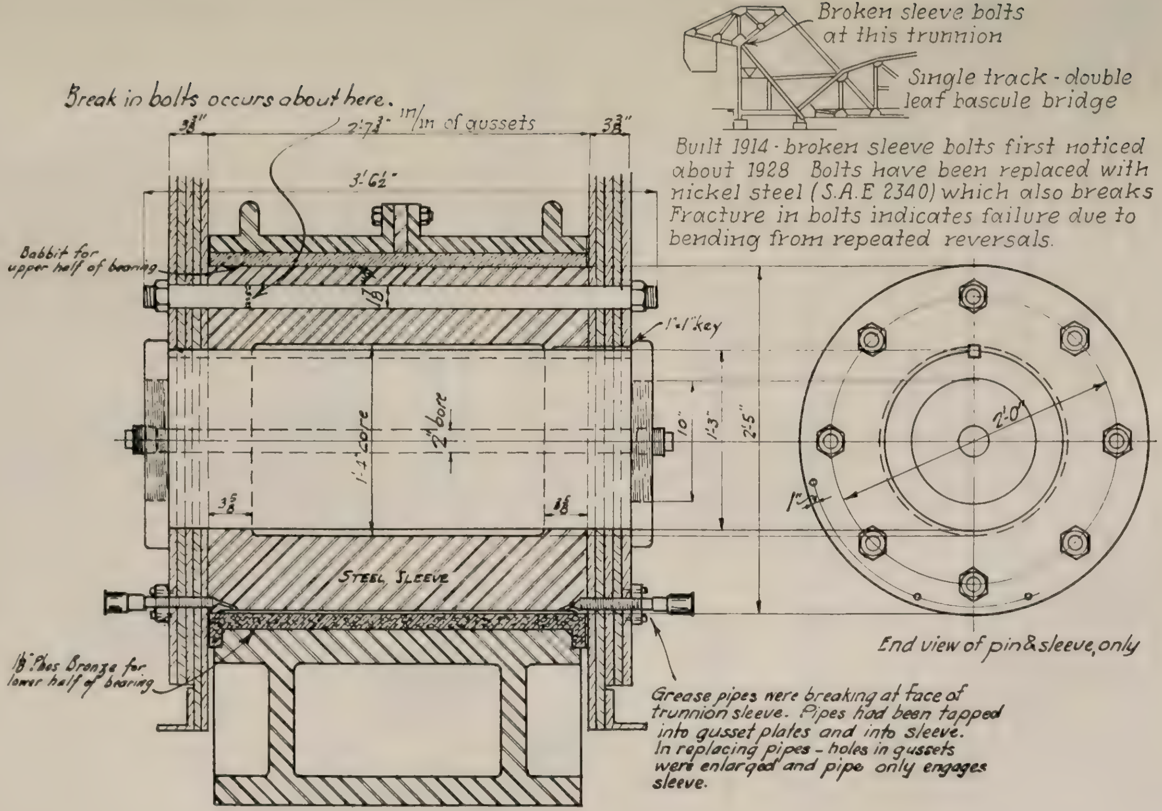
B. R. Leffler (chairman, subcommittee), F. E. Bates, J. E. Bernhardt, A. W. Carpenter, C. H. Chapin, O. F. Dalstrom, R. P. Davis, G. A. Haggander, S. Hardesty, C. S. Heritage, A. R. Ketterson, A. M. Knowles, P. G. Lang, Jr., H. S. Loeffler, F. J. Pitcher, C. S. Sheldon, I. L. Simmons, G. L. Staley, G. H. Tinker, G. H. Trout, E. Weidemann, H. T. Welty, A. R. Wilson.

In the study of this subject, letters were sent to a number of railroad bridge engineers, requesting them to send in sketches of faulty bridge details, as actually observed in existing bridges. Some of the sketches received show what occurred and the causes as understood by the bridge engineers who sent in the sketches.

The report is now presented, with illustrations of the faulty details and discussions of the major points of interest. Reference to the sketches will be by "Fig. Nos.", there being no mention of any railroad by name or of any source of information.

Fig. 1 shows a defective design in the main counterweight bearing of a bascule bridge. The bearing is faulty in that the designer assumed there would be no stress on the bolts. The design is of such a nature that the stress determination can not be made; such undeterminable stresses often occur in a detail having too many parts. Six members of the committee reported similar failures.

Fig. 2 shows a common faulty detail. In this detail, the designer assumed that there would be no play between the pin and connecting members. The end post is also rigidly connected to the top chord by the riveted portal bracing in such a way that any wear throws undue stress on the bent plate connecting the portal to the top chord thus causing


Broken sleeve bolts at this trunnion
Single track - double leaf bascule bridge
Break in bolts occurs about here.
3⅜"
2'-7¾" in/in of gussets
3⅜"
3'-6½"
Babbit for upper half of bearing
⅛
1"×1" key
10"
1'-3"
2'-5"
2'-0"
1"
1'-1" core
2" bore
3⅝
3⅝
Steel Sleeve
⅛" Phos Bronze for lower half of bearing
End view of pin & sleeve, only

Built 1914 - broken sleeve bolts first noticed about 1928 Bolts have been replaced with nickel steel (S.A.E 2340) which also breaks Fracture in bolts indicates failure due to bending from repeated reversals.

Grease pipes were breaking at face of trunnion sleeve. Pipes had been tapped into gusset plates and into sleeve. In replacing pipes - holes in gussets were enlarged and pipe only engages sleeve.

Section view of trunnion & bearing

FIG. 1

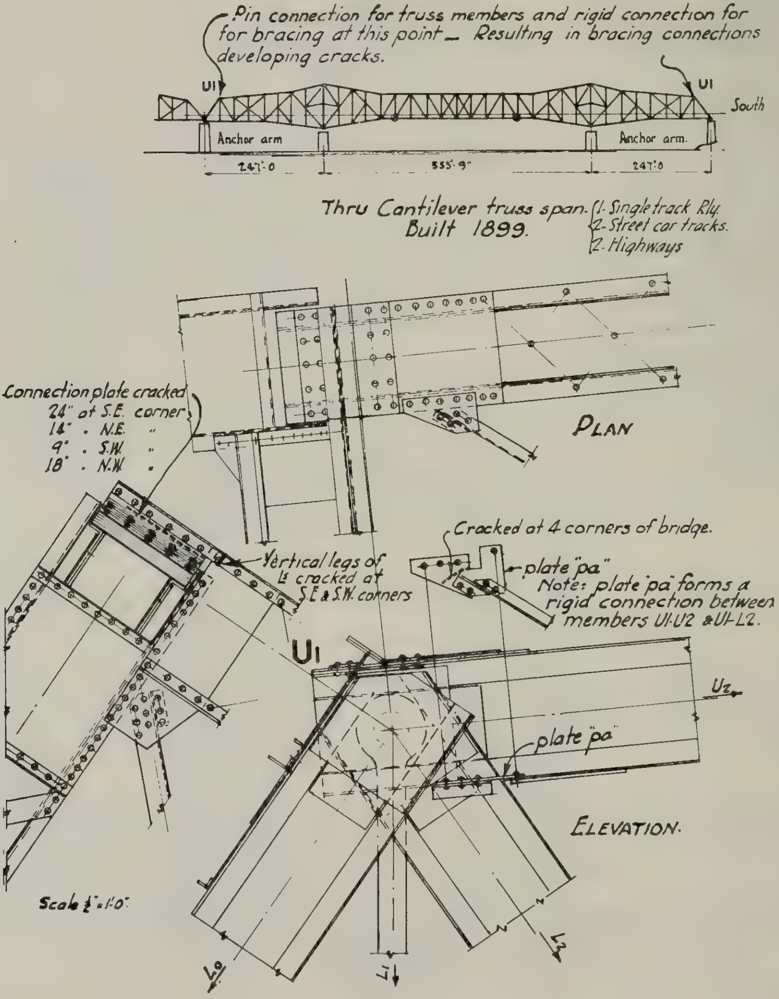

Pin connection for truss members and rigid connection for
for bracing at this point — Resulting in bracing connections
developing cracks.
U1
U1
South
Anchor arm
Anchor arm.
247'-0
555'-9"
247'-0
Thru Cantilever truss span.
Built 1899.
1-Single track Rly.
2-Street car tracks.
2-Highways
Connection plate cracked
24" at S.E. corner
14" " N.E. "
9" " S.W. "
18" " N.W. "
PLAN
Cracked at 4 corners of bridge.
plate "pa"
Note: plate "pa" forms a
rigid connection between
members U1-U2 & U1-L2.
Vertical legs of
Ls cracked at
S.E & S.W. corners
U1
U2
plate "pa"
ELEVATION.
Scale ½"=1'-0"
L0
L1
L2

FIG. 2

a crack in the connection. The diagonal is connected in a similar way by a badly shaped plate having re-entrant cut from which the crack started.

Fig. 3 illustrates the damaging effects of a re-entrant cut in a plate. The determination of the stress tending to cause a crack at such a location is impossible from a practical standpoint. The re-entrant cut, we know, causes high localized stress. The bottom chord channels might have been turned inward, thus avoiding the notching or cutting of the floor beam web, or else the web reinforced.

Fig. 4 is also an illustration of the bad effect of a re-entrant cut. It is probable that the designer of this detail assumed that the bottom gusset plate connecting the lower flange of the floor beam to the chord, would serve as an adequate tension detail and prevent any tension stress occurring in the re-entrant cut. It should be noted that the gusset plate is rather deep yet the floor beam cracked at this cut.

Fig. 5 shows a longitudinal crack along the root of the angle in the top flange of a stringer. Three such failures are shown, two of the cracks being on the inside and one on the outside.

Fig. 6 shows an old and faulty detail. The rollers are too small and no adequate distribution over the rollers is assured. Such roller nests are ideal arrangements for col-

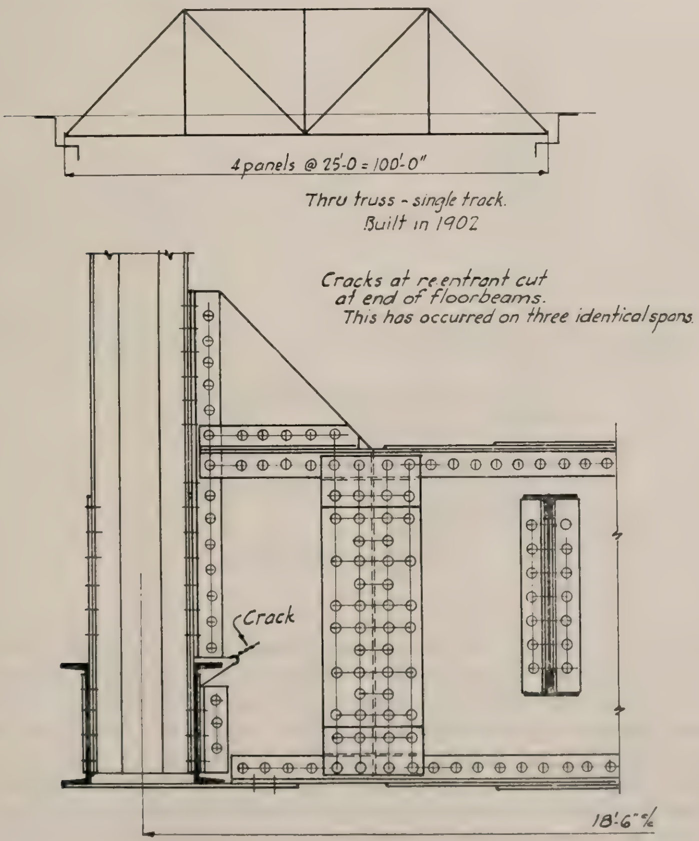
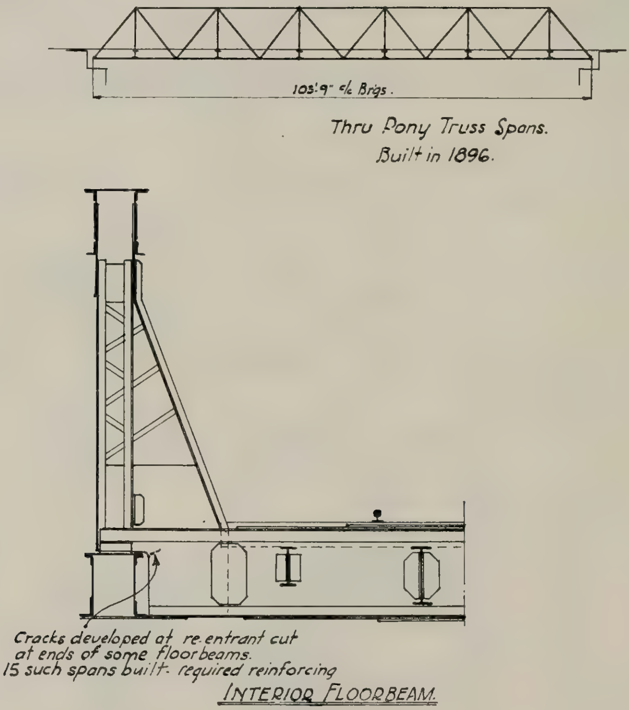

4 panels @ 25'-0 = 100'-0"
Thru truss - single track.
Built in 1902
Cracks at re-entrant cut
at end of floorbeams.
This has occurred on three identical spans.
Crack
18'-6" c/c

Fig. 3

lecting dirt and rust. Large rolling friction that causes a horizontal pull on the abutment ensues, increasing the tendency of the abutment to tip. There are some recent rocker designs, with a pin as a hinge, which give promise of greater satisfaction than this old-style roller nest.

Fig. 7 shows a column supporting two abutting plate girders. The lower flange of the main girder has broken at the edge of the column cap, the stiffeners cutting down through the flange and bending the overhanging portion of the column cap. This detail also places an eccentric load on the column.

It is probable that in a column supporting two abutting spans, it is not possible to avoid eccentric loading. This detail would have been better had the stiffeners been placed directly over the column and as near the center of the column as practicable. The outstanding leg of the cap angle should have had supporting stiffeners.



Thru Pony Truss Spans.
Built in 1896.

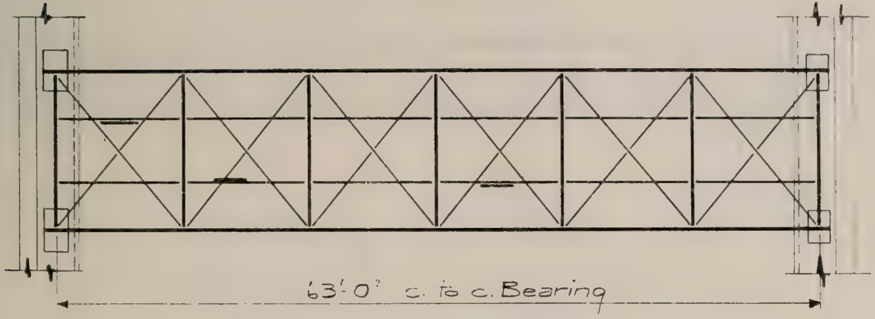
Cracks developed at re-entrant cut at ends of some floorbeams.
15 such spans built- required reinforcing

INTERIOR FLOORBEAM.

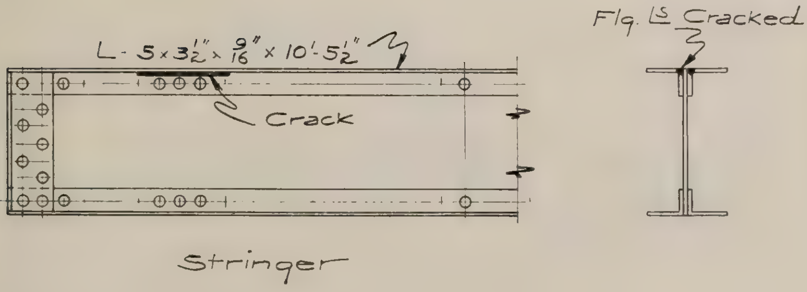
FIG. 4

It should be noted that the flange of the shallower girder also broke at the edge of the column cap; this was due, no doubt, to the excessive local bending or shearing action.

Fig. 8 shows broken bent plates connecting an end floor beam to a through truss. The bottom flange of the outstanding leg of the floor beam is also cracked near the roller nest upon which the floor beam rests. It should be noted that the crack occurred near the ends of the bottom cover plate and of the adjacent sole plate. It appears that it would have been better to extend the cover plate the full length of the floor beam. It is difficult to give a stress analysis that will account for the high stresses resulting in this crack.

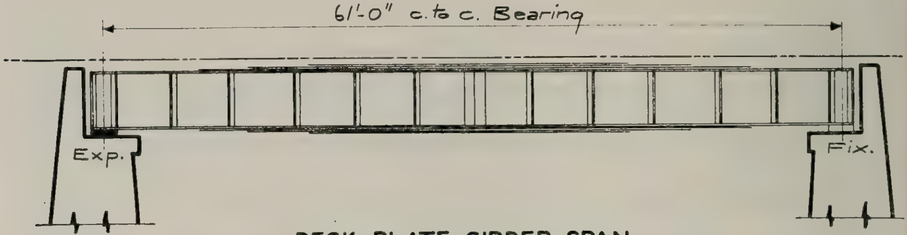


THRU PLATE GIRDER SPAN
BUILT 1908

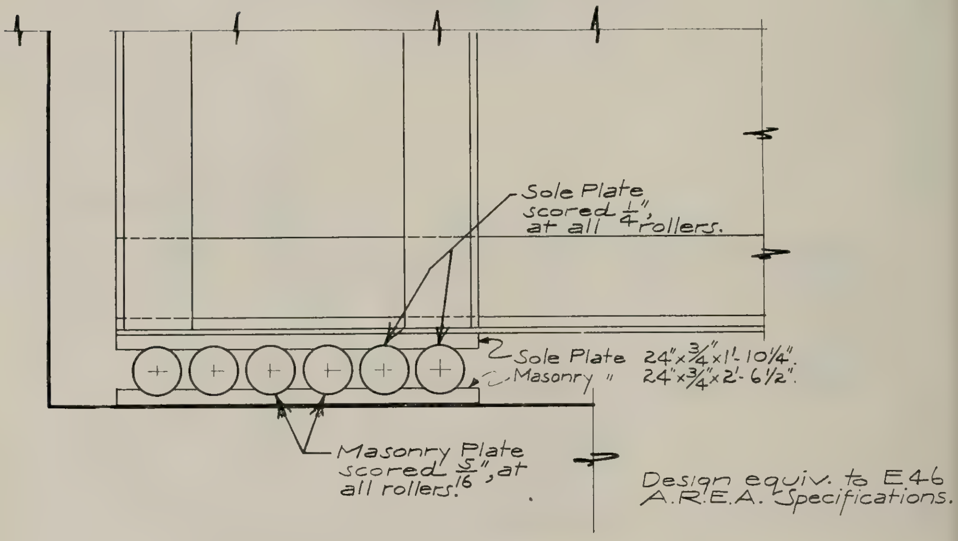


Max Axle Loading (1908 to 1928) 66,260 #
" " " (1928 to present time) 72,000 #

Fig. 5



DECK PLATE GIRDER SPAN
BUILT 1913


Sole Plate scored 1/4", at all rollers.
Sole Plate 24"x3/4"x1'-10 1/4".
Masonry " 24"x3/4"x2'-6 1/2".
Masonry Plate scored 5/16", at all rollers.

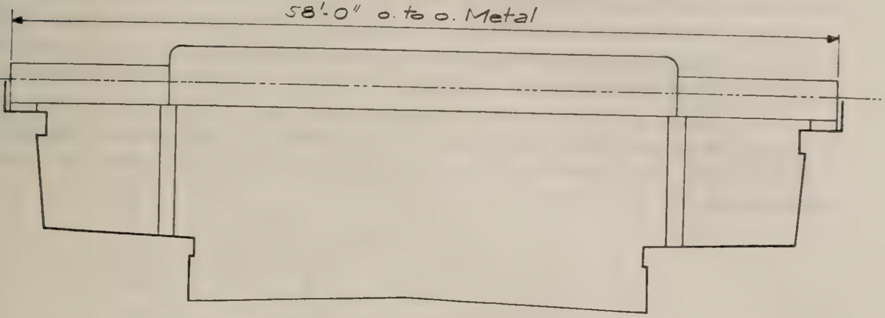
Design equiv. to E46
A.R.E.A. Specifications.

Original Diam. of Rollers 3 1/4",
Reduced to 3" to 2 3/4".
Roller & Plate material is
ordinary structural steel grade.

Operating Load

D.L. = 22,000#
L.L. = 172,000#
I. = 153,000#
347,000#
= 930d.

FIG. 6



THRU PLATE GIRDER BRIDGE
BUILT 1901

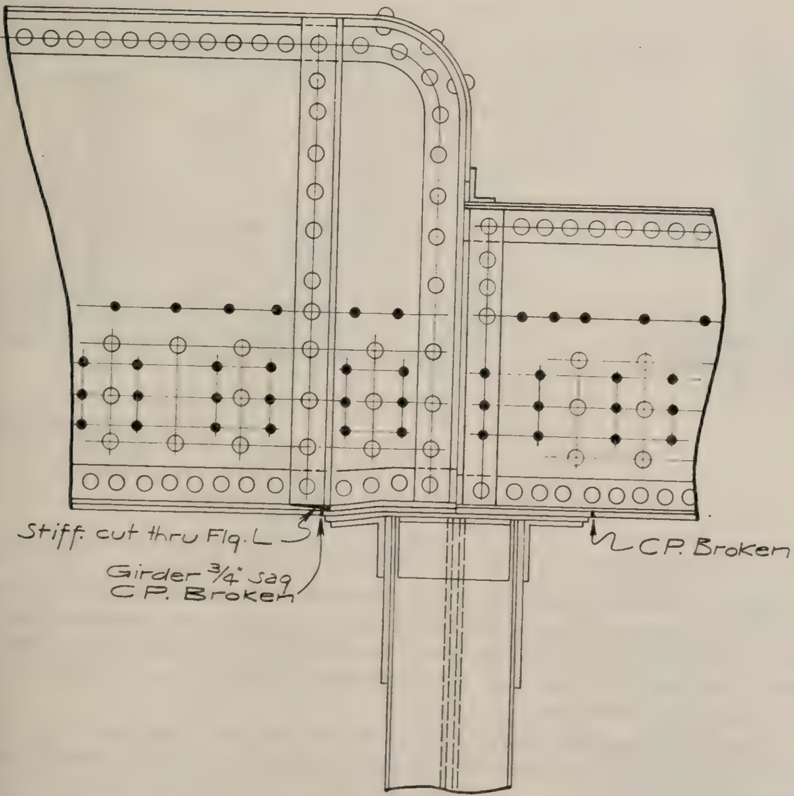


FIG. 7

The crack in the bent plate probably is due to the cause illustrated in Fig. 2; that is, an attempt to make a pin joint and a riveted joint at the same point work together.

Some of the connection angles of the stringers have cracked in the roots at the top. The stringers act as partially continuous beams, but the connection angles are not capable of taking care of the end moment.

Fig. 11 shows a common fault in designing where two abutting girders are riveted together. The shallow girder should have been supported by a shelf securely attached to the deep girder, and only enough rivets connecting the two girders to anchor the shallow girder against lateral movement.

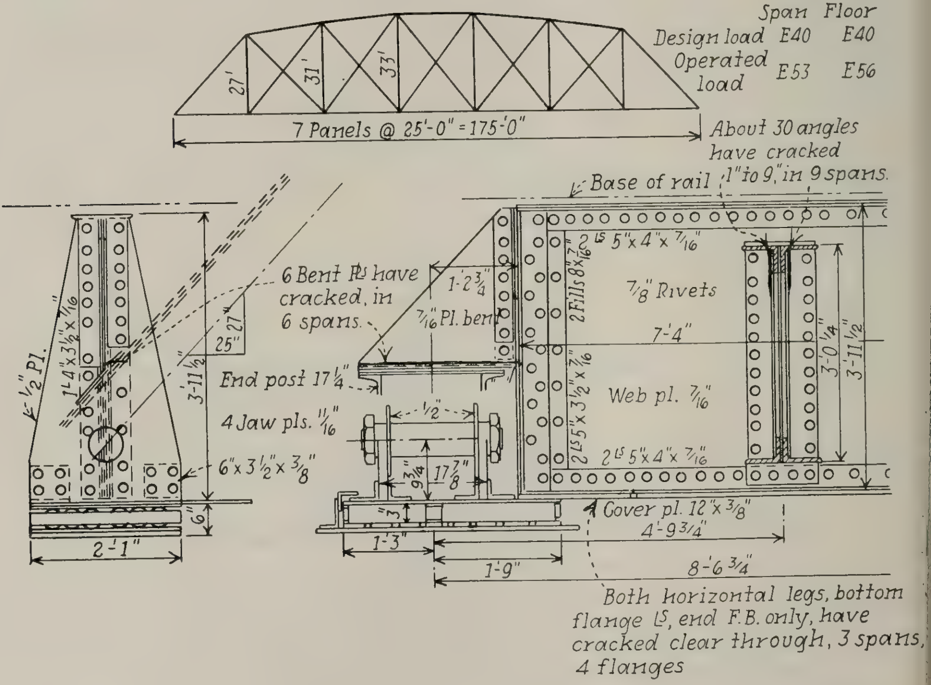


Fig. 8

Figure 13 shows what happens in a pin-connected counter under reversal of stress. It should be remembered that an eye-bar counter is subject to the complete release of stress. The assumption also is made that it does not take any compression, which, of course, is incorrect, as it must take some compression. There is, thus, actually reversal of stress in the pin connections.

The sleeve nut was provided to take up the slack in the counter, caused by wear. An open turnbuckle would have been better, because it would have allowed easy inspection.

Fig. 14 also shows a poor seating of abutting plate girders on the top of a column. The defects and causes are similar to those shown in Fig. 7.

Figs. 9, 10, 12 and 15 show failures of small details. Those in the examples of skew bridges should be particularly noted.

Figures 16 to 21, inclusive, are interesting, and the defects are obvious in most of them.

Fig. 16 shows a failure that is interesting because the reason is not obvious. Here an attempt was made to have the main bottom chord of the truss act as a chord of the lateral truss.

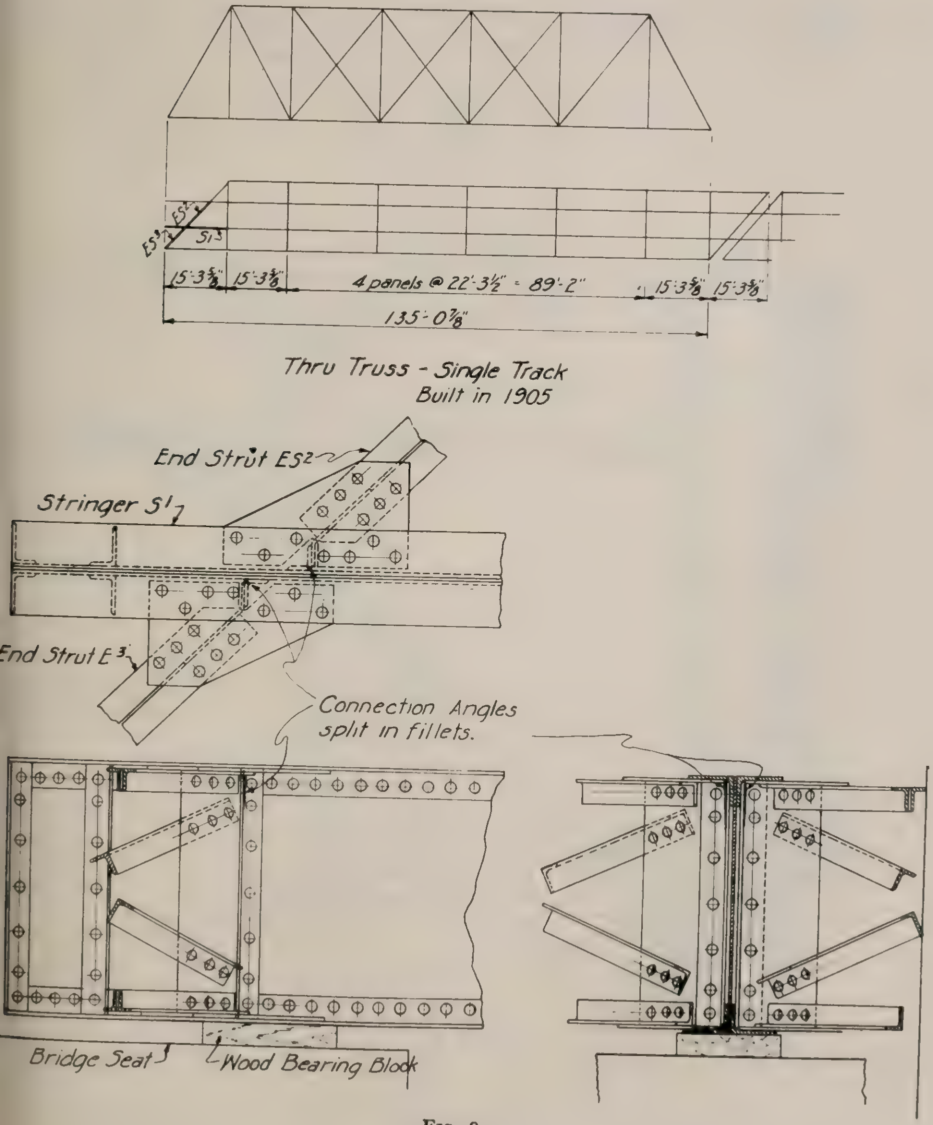
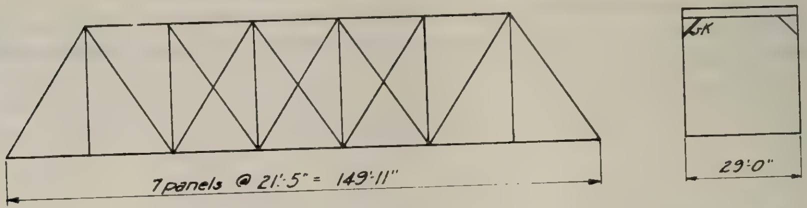
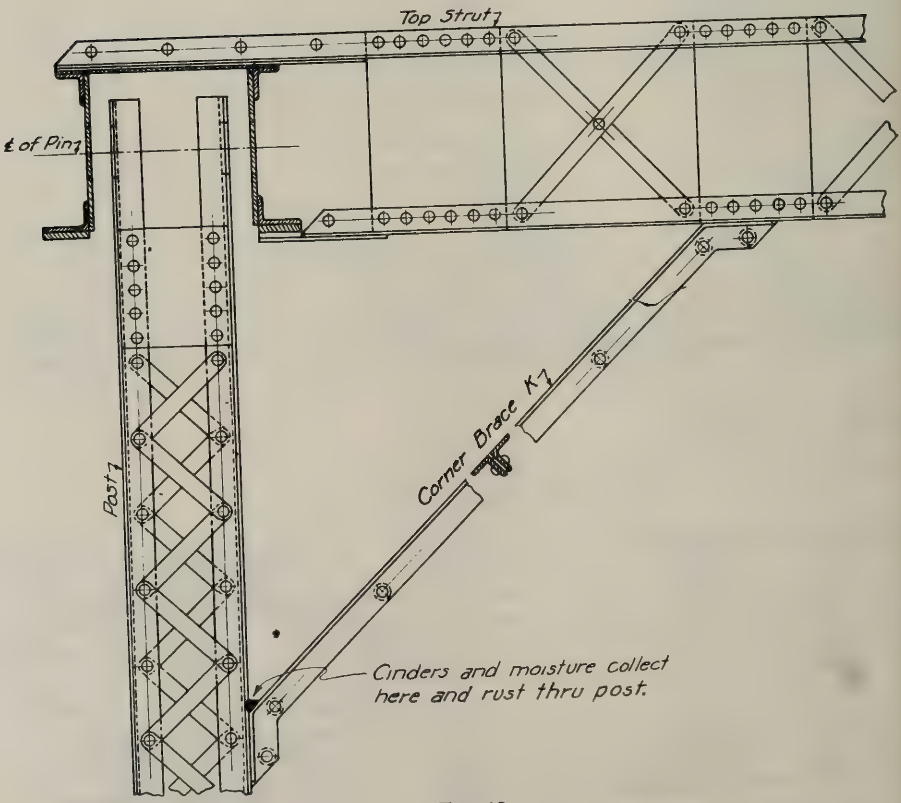


FIG. 9



Thru Truss - Double Track
Built in 1902

Inter. Section



Cinders and moisture collect here and rust thru post.

FIG. 10

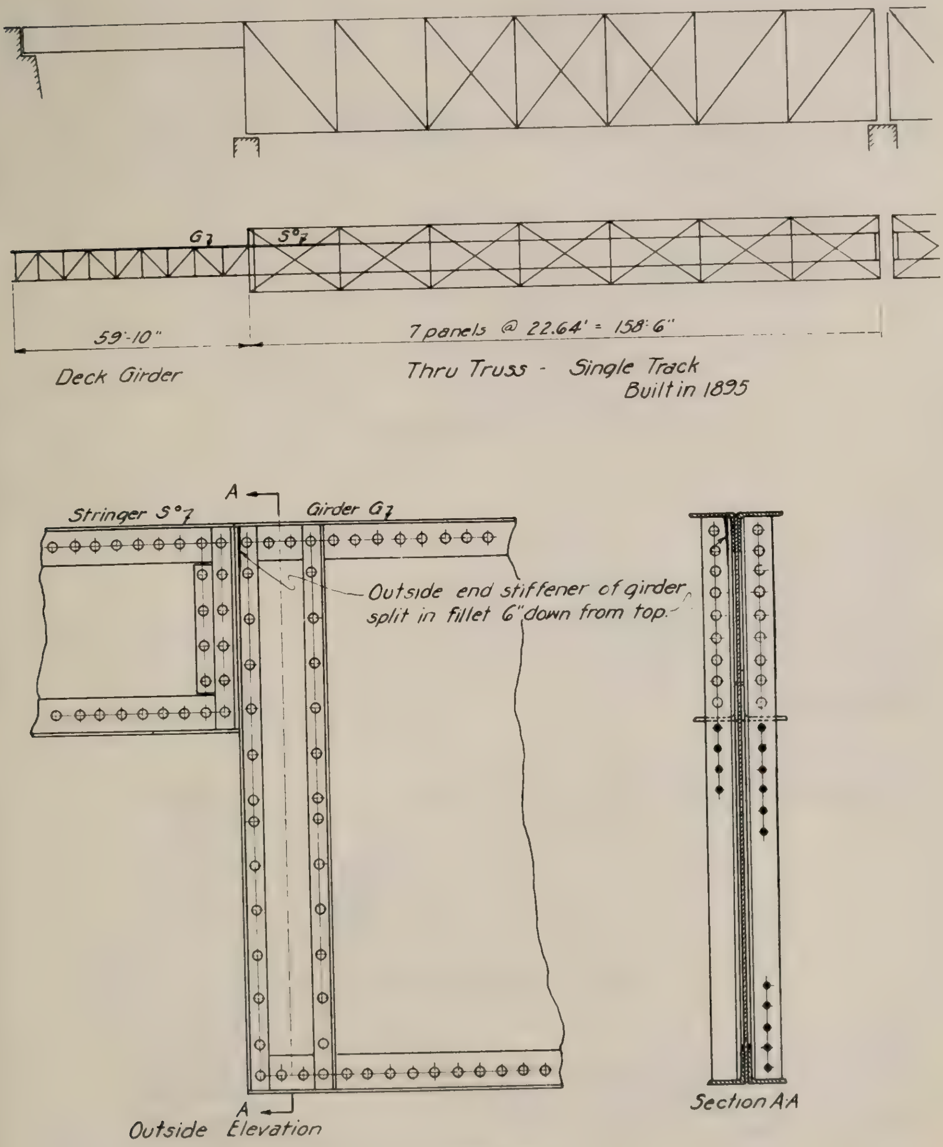

G7
S°7
59'-10"
7 panels @ 22.64' = 158'-6"
Deck Girder
Thru Truss - Single Track
Built in 1895
A
Stringer S°7
Girder G7
Outside end stiffener of girder, split in fillet 6" down from top.
A
Outside Elevation
Section A-A

FIG. 11

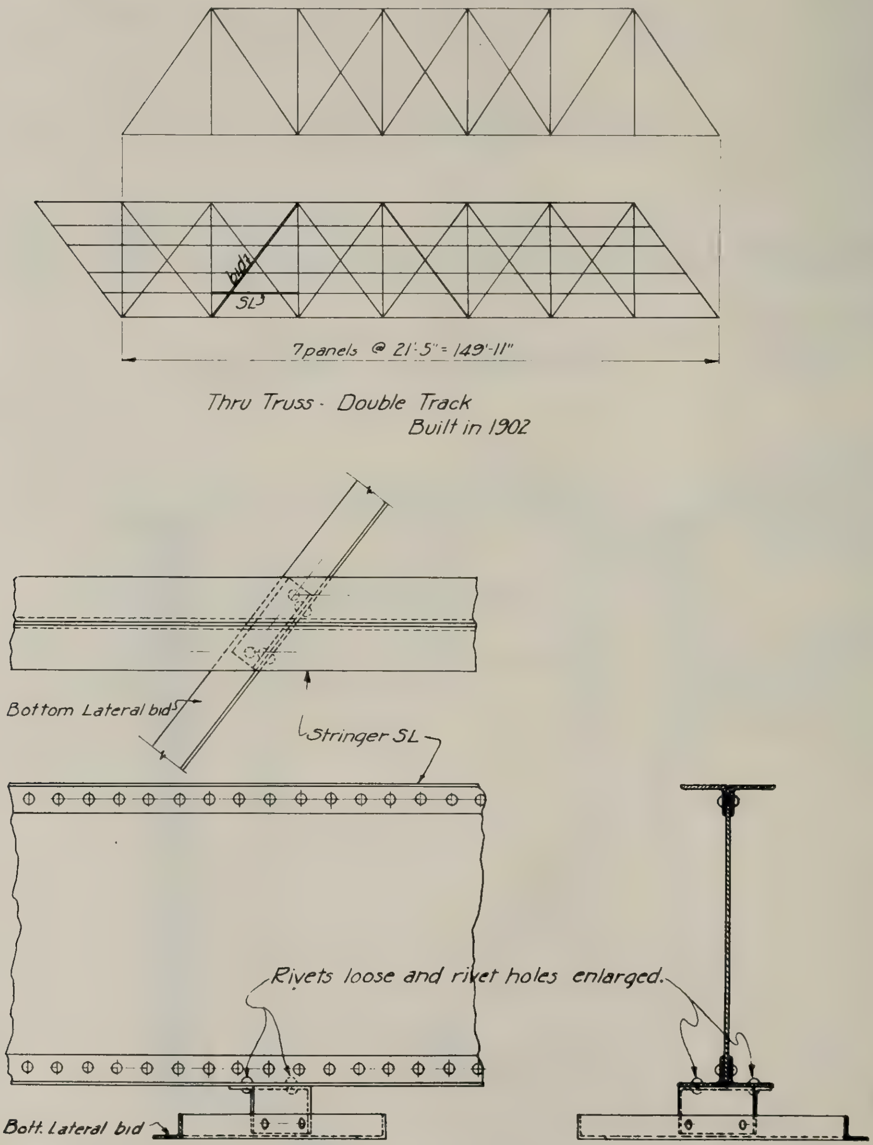
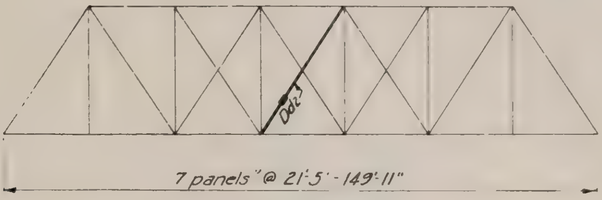

bid5
SL3
7 panels @ 21'-5" = 149'-11"
Thru Truss - Double Track
Built in 1902
Bottom Lateral bid5
Stringer SL
Rivets loose and rivet holes enlarged.
Bott. Lateral bid

FIG. 12

As a train passes over a bridge lateral vibration is set up and the vibration causes stress in the bottom lateral system. The stress must reach the chord through the short length of the floor beam, that extends from the lateral connection to the channel face of the post. The weakest part of the floor beam is the lower part of the web at the end where the bottom flange angle stops.

Let us see what happens at this point. When a train passes over the bridge the lateral vibration causes reverse bending in the floor beam web, as the floor beam web attempts to transmit stress into the bottom chord. This action is like that of a wire being bent back and forth while held in a vise. Only the lower part of the floor beam web is materially affected.



Thru Truss - Double Track
Built in 1902

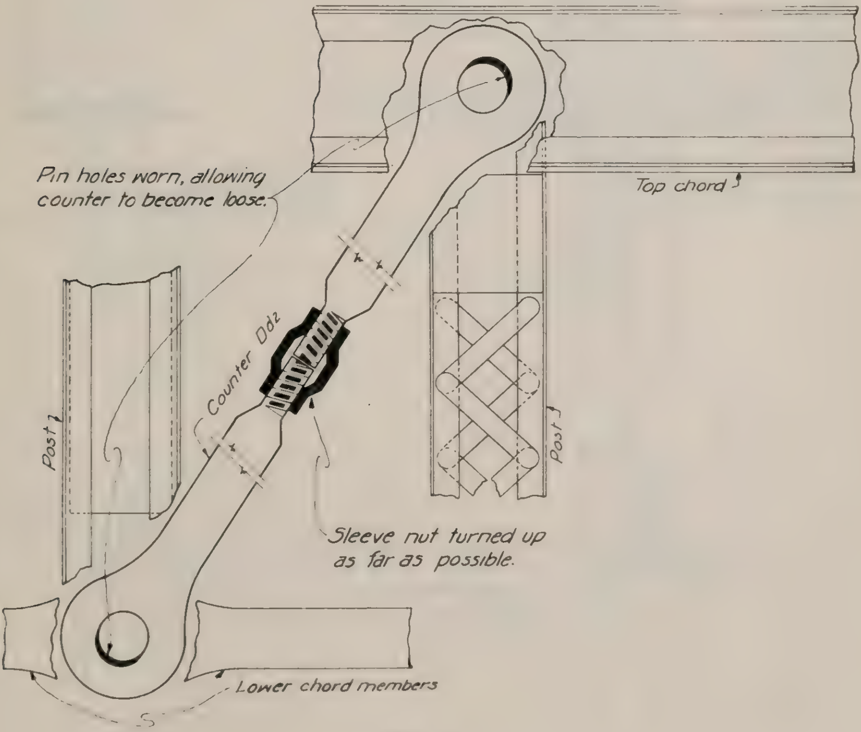
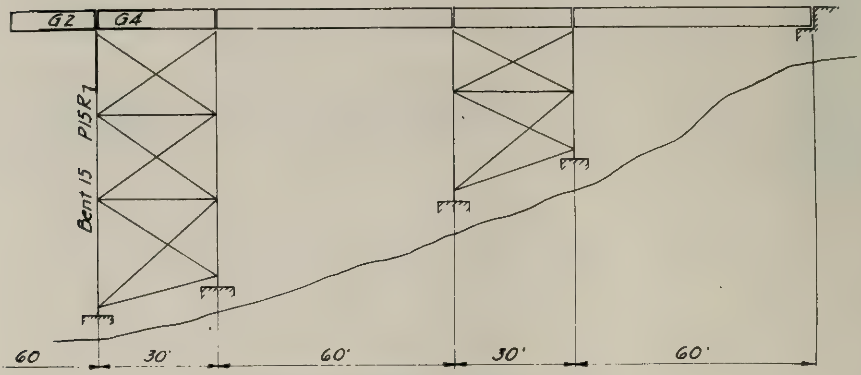

Pin holes worn, allowing counter to become loose.
Top chord
Counter Dd2
Post
Post
Sleeve nut turned up as far as possible.
Lower chord members

Fig. 13



Deck Girder Viaduct - Single Track
Built in 1902

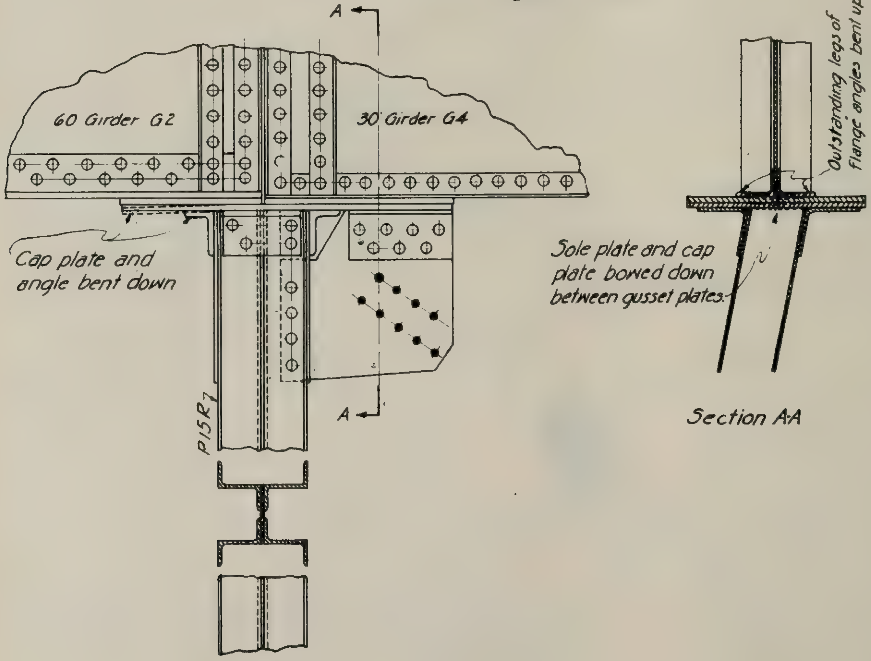
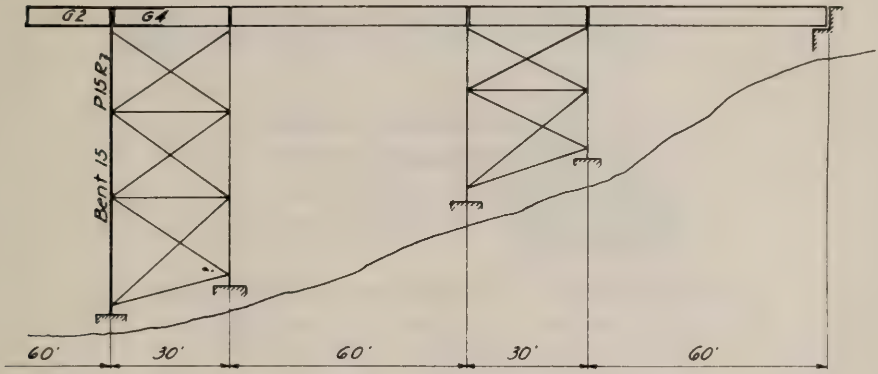

A
60 Girder G2
30' Girder G4
Cap plate and angle bent down
P15R7
A
Outstanding legs of flange angles bent up.
Sole plate and cap plate bowed down between gusset plates.
Section A-A

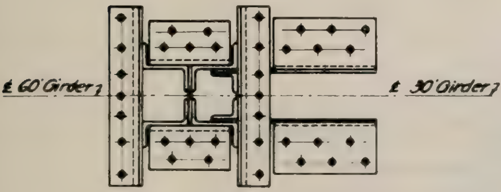
FIG. 14

Any lateral force, such as wind acting on the bridge, will cause similar stresses. There will be reversal from wind, as the wind reverses its direction, which may cause vibration in the span.

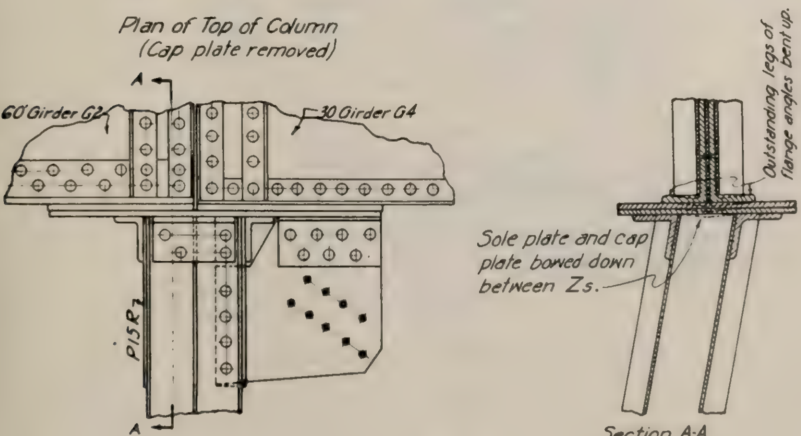
A remedy is shown in Fig. 16, being provided by inserting an independent chord for the lateral system. However, the remedy does not relieve the floor beam web entirely of stress, as the new chord must also deform, and this in turn will throw some stress into the bottom chord of the main truss. The reinforcing plates, however, may give



Deck Girder Viaduct - Single Track
Built in 1902

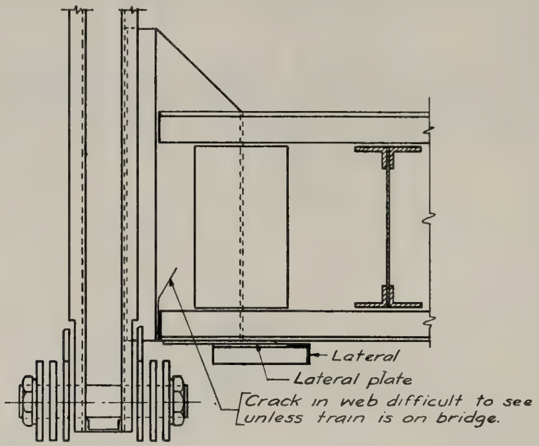


Plan of Top of Column
(Cap plate removed)


A
60' Girder G2
30' Girder G4
P15R
A
Sole plate and cap plate bowed down between Zs.
Outstanding legs of flange angles bent up.

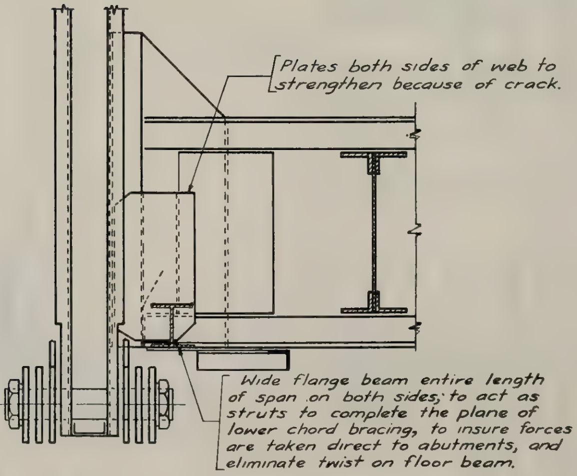
Section A-A

FIG. 15



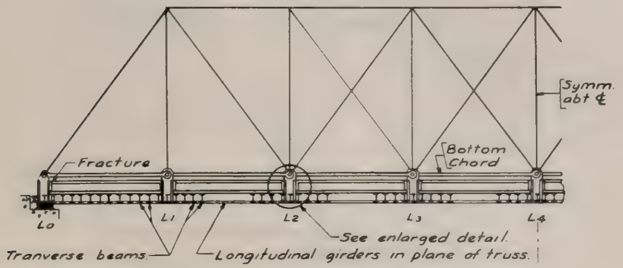
FLOOR BEAM OF PIN CONNECTED TRUSS SPAN

Forces carried to floor beam by lateral plate can result in fracturing of floor beam web.


Plates both sides of web to strengthen because of crack.
Wide flange beam entire length of span on both sides, to act as struts to complete the plane of lower chord bracing, to insure forces are taken direct to abutments, and eliminate twist on floor beam.

REMEDY FOR ABOVE CONDITION

Fig. 16



TRUSS SPAN WITH TRANSVERSE BEAM FLOOR FRAMING INTO LONGITUDINAL GIRDERS.

LONGITUDINAL GIRDERS NOT ONLY ACT AS BEAMS BETWEEN PANEL POINTS, BUT ALSO AS BOTTOM CHORDS, CAUSING END CONNECTION ANGLES TO CRACK IN FILLETS, USUALLY AT POINTS Lo

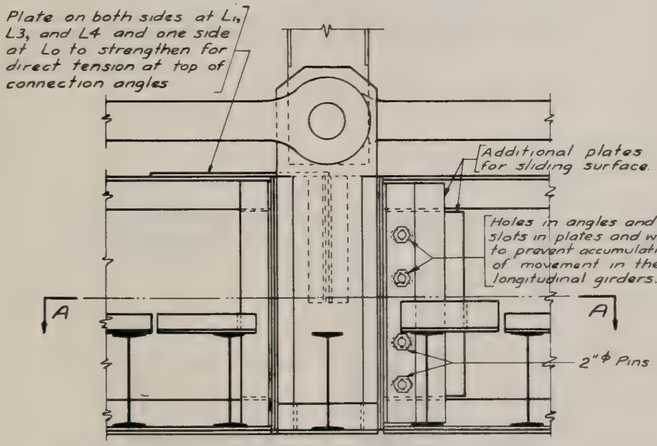
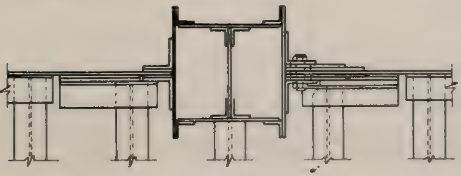


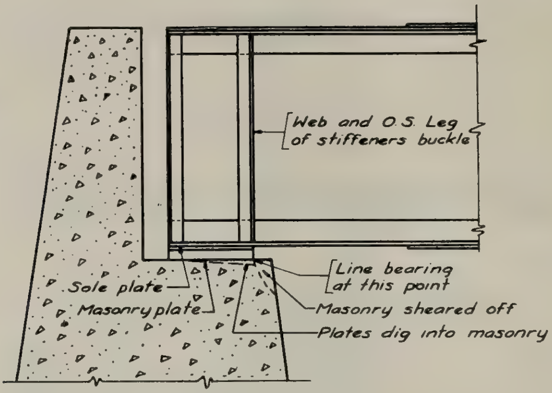
Plate on both sides at L1, L3, and L4 and one side at Lo to strengthen for direct tension at top of connection angles
Additional plates for sliding surface.
Holes in angles and slots in plates and web to prevent accumulation of movement in the longitudinal girders.
A
A
2"ϕ Pins

ENLARGED DETAIL OF PANEL POINT L2
REMEDY FOR ABOVE NOTED FAILURE



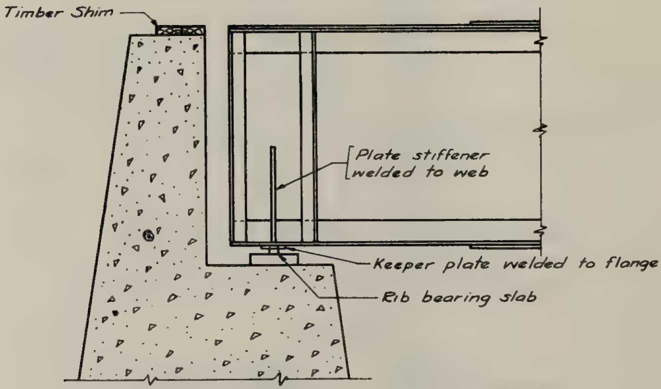
SECTION A-A

FIG. 17



END BEARINGS OF GIRDER SPANS

OLDER DESIGN OF GIRDERS CARRYING
HEAVIER POWER RESULTS IN LARGE DEFLECTIONS



REMEDY FOR FAILING END BEARINGS

CENTRALIZED BEARING SAVES MASONRY
AND INSURES FREE ACTION OF SPAN

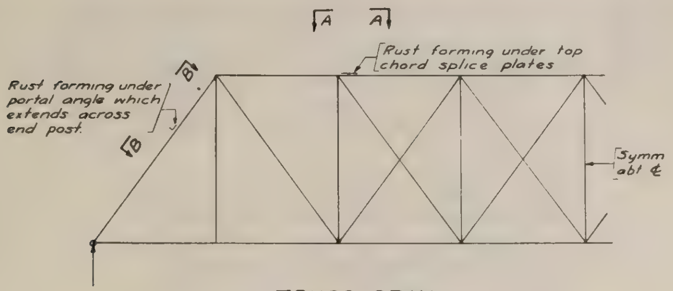
FIG. 18

sufficient section to take care of that part of the stress which is transmitted to the bottom chord.

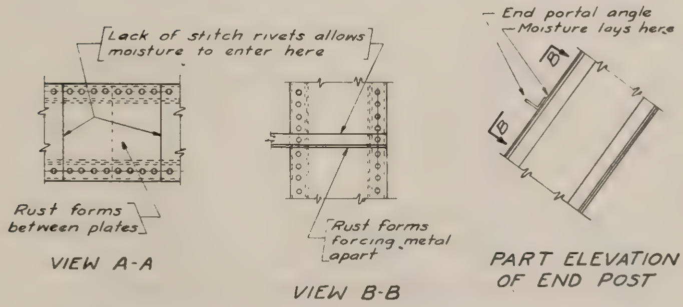
The cause of the failures shown in Fig. 17 is evident. Here is a basic error in the design assumptions. It is assumed that the bottom chord takes all the tensile stress. This never is the case if there is another continuous member extending from one end of the truss to the other. The deformation of the eye-bar bottom chord is bound to throw stress into the continuous stringers.

Referring to Fig. 18: Here again the defect lies in the improper location of the end stiffeners. The deflection of the girder throws most of the load on the outer edge of the concrete bridge seat, causing spalling or failure of the concrete at the outer edge.

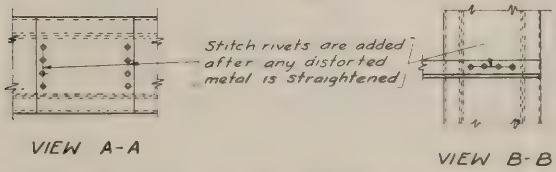
Figures 22 to 31, inclusive, show a number of interesting failures of details.


A
A
Rust forming under top chord splice plates
B
Rust forming under portal angle which extends across end post
B
Symm abt ℄

TRUSS SPAN
INDICATING WHERE RUST FORMS TO CAUSE LOSS OF SECTION OF TOP CHORD AND END POST


Lack of stitch rivets allows moisture to enter here
End portal angle
Moisture lays here
B
B
Rust forms between plates
VIEW A-A
Rust forms forcing metal apart
VIEW B-B
PART ELEVATION OF END POST

ENLARGED DETAIL OF ABOVE NOTED DETERIORATION


Stitch rivets are added after any distorted metal is straightened
VIEW A-A
VIEW B-B

ENLARGED DETAIL OF REMEDY FOR ABOVE NOTED DETERIORATION

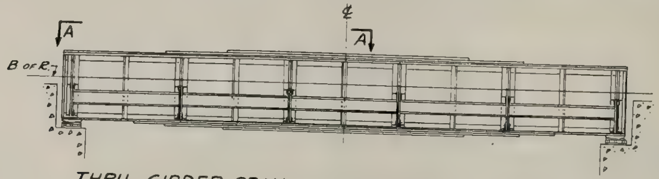
FIG. 19

Fig. 22 shows a hip vertical hanger for the floor beam of a through truss. This hip vertical broke through Section AA. It should be noted that the average net tensile stress, with almost 100 percent impact, is only 22,100 lb. per sq. in.

The structure is at the entrance to a yard where there is a large amount of switching back and forth over it. Such switching may produce greater fatigue than is found in a bridge at a location where speeds are high.

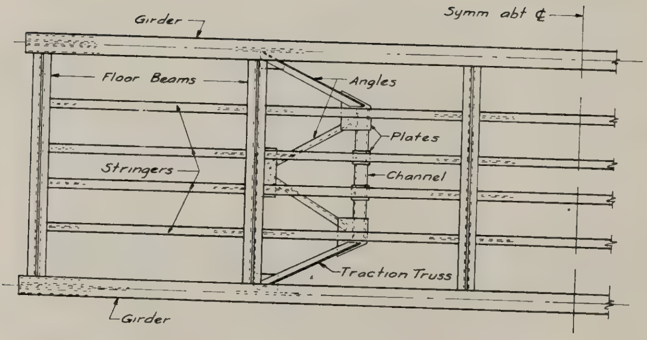
Fig. 23 shows a similar break. Here the average unit stress was 18,900 lb.

Fig. 24 shows the details of the hip vertical of a double-track, through-truss swing bridge. In this case the fault lies in the insufficient net section back of the pin hole.



THRU GIRDER SPAN NEAR CURVES OR ON GRADE

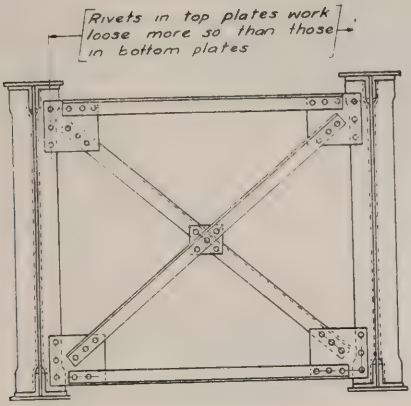
UNDER TRACTION AND BRAKING ON THRU GIRDER SPANS ON HEAVY GRADES AND NEAR ENDS OF CURVES, THE FORCES ARE TAKEN TO THE MAIN GIRDERS THRU THE TOP FLANGES OF THE FLOOR BEAMS WITH CONSEQUENT WORKING AND DAMAGE AT FLOOR BEAM CONNECTIONS TO MAIN GIRDERS.



PLAN VIEW A-A

ABOVE NOTED WEAKNESS REMEDIED
BY PLACING TRACTION TRUSSES

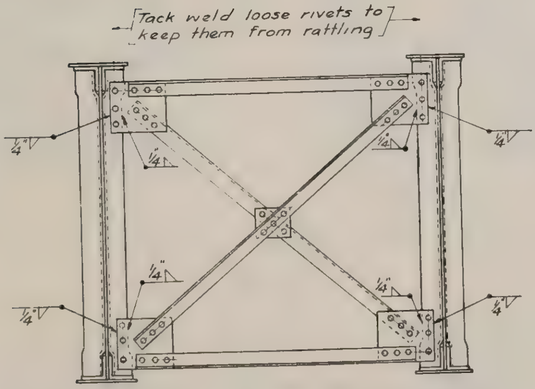
Fig. 20



Rivets in top plates work loose more so than those in bottom plates

CROSS FRAMES OF DECK GIRDER SPANS

HIGH SPEEDS RESULT IN HEAVY SIDE THRUST, AND THREE AND FOUR RIVET CONNECTION OF CROSS FRAME TO GIRDERS WORK LOOSE



Tack weld loose rivets to keep them from rattling

REMEDY FOR ABOVE CONDITION

AN ECONOMICAL METHOD OF CORRECTION IS BY WELDING CROSS FRAME PLATES TO STIFFENER ANGLES

Fig. 21

This broken detail was difficult to detect, as the cover plate of the top chord completely hid the detail. An examination of the design drawing indicated that this detail should fail. In opening the top chord, incipient cracks were found on Section CC.

Fig. 25 shows the details of the center bearing of a swing bridge. Briefly, the weight of the span is carried on a pivot; this pivot is composed of two cast iron parts with a bronze disk between them. The whole weight of the bridge, when swinging, is carried by hanger bolts through an I-beam grillage that rests on top of the top casting. When the bridge is closed, side wedges are expected to lift the spans so as to relieve the center bearing of the live load.

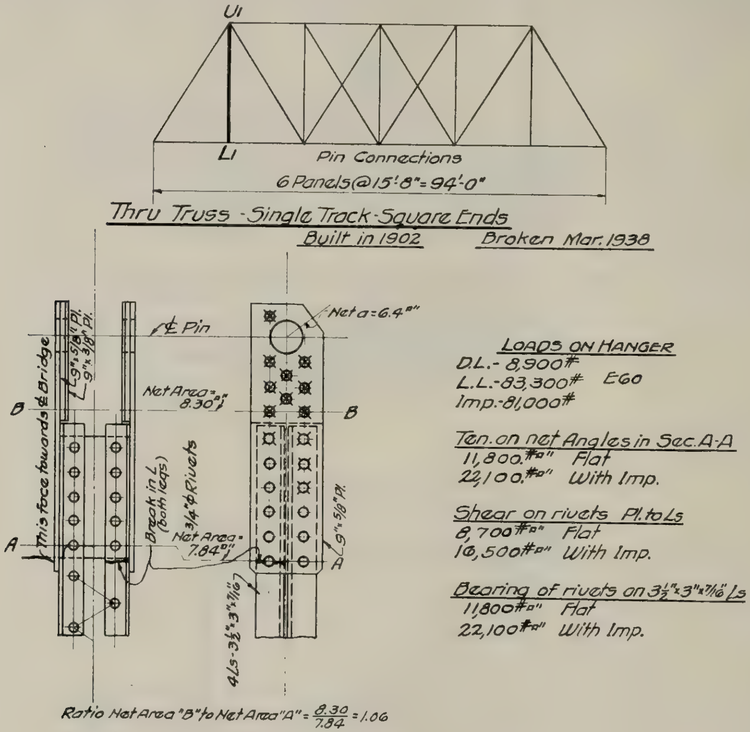


FIG. 22

The side wedge may not be effective under all conditions. The difficulty lies in getting the side wedges fully driven and kept in that position every time that the drawbridge is closed. The wear of machinery parts soon makes the effectiveness of such wedge action doubtful. In spite of this defective side wedge detail, the drawbridge functioned in this respect 43 years. Failure then occurred by the crushing of the cast iron top of the pivot, and the breaking of some of the hanger bolts in the root of the thread.

Fig. 25 also shows a toggle end lift, that kicked out under traffic, lowering the ends of the span. Such a toggle arangement is defective because it can not be kept in a straight line after the bridge is closed; a slight out-of-line position can not be held securely by the operating machinery. This toggle has been kept in service but a device was added that prevents the toggle from kicking out.

Fig. 26 shows the failure of a compression member with forked ends made necessary by the pin connection. It is difficult to account for a failure of this kind, on the supposition that all parts of the column are under compression but, apparently, under swaying of the truss (this being a deck truss) tension is introduced at the re-entrant cut, resulting in final breaking.

The same remarks apply to Fig. 27. This is a case of a bad re-entrant cut. In this and the previous case, rough gouging-out of the re-entrant cut was done in fabrication.

Fig. 28 shows a clear-cut case of a hip vertical failure at the pin joint. Here the failure was through the pin plate and was due to not having enough metal surrounding the pin. The net section through the pin hole along Line BB is slightly less than the net section through the body of the member at Section AA. Good designing requires that the net section on BB be 40 percent greater than on AA, and the Section CC back of the pin not less than the net section at AA.

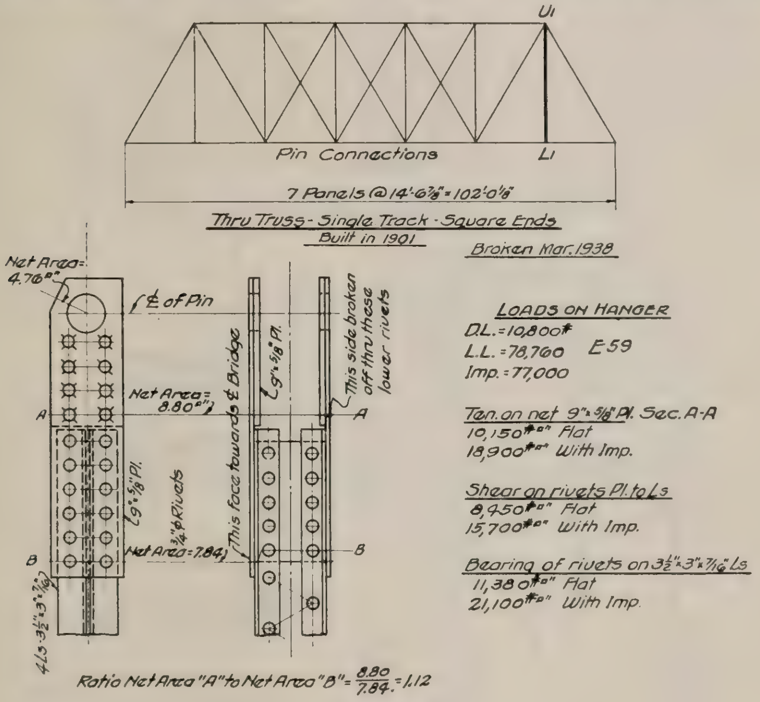


FIG. 23

Fig. 29 shows a poor detail for a floor-beam connection to the main post of a through truss. The bottom chord of this truss is composed of eye-bars; the re-entrant cut in the floor beam was made to clear the heads of the eye-bars and the pin. The drawing shows a failure through the rivets. This particular detail is interesting in that it was difficult to detect the incipient cracking of the web, because the edge of the web was hidden.

The detail also shows a wide horizontal gusset plate that connects the bottom of the main truss post to the lower flange of the floor beam. Probably, the designer thought that this gusset would serve as a strengthening element of the detail. To the gusset plate were also attached the bottom laterals of the truss.

Figures 30–A and 30–B show the anchorage of a long cantilever bridge built as late as 1910.

Eye-bars extend down many feet into the masonry. They were pre-stretched by the wedges and kept in this pre-stretched condition. These main anchor bars are not subject to complete release or reversal of stress.

The links, which transmit the reactions to the main anchor rods, were subject to reversal of stress. The pin holes through the chord and through the links were considerably enlarged through wear as shown on the right-hand side of Fig. 30-B. These links were renewed, and the holes rebored and bushed. To do this work, it was necessary to hold the span by other means during the work on the repairs. Traffic was carried without any serious interruption.

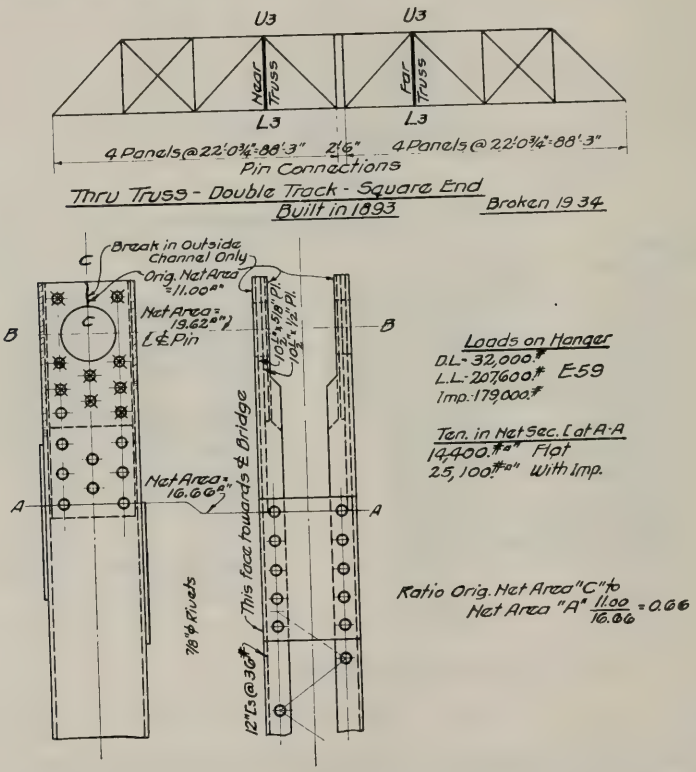


FIG. 24

Fig. 31 shows the end-lift screws of an ordinary swing bridge. The note in the lower part of the drawing gives an account of the difficulty encountered. A fin-like sliver broke from the thread of the bushing and wedged the screw, making it impossible to operate the screws. The fault lay in making the end of the screw thread in the shape of a fin or knife edge. New bushings were obtained, with the end of the thread rounded.

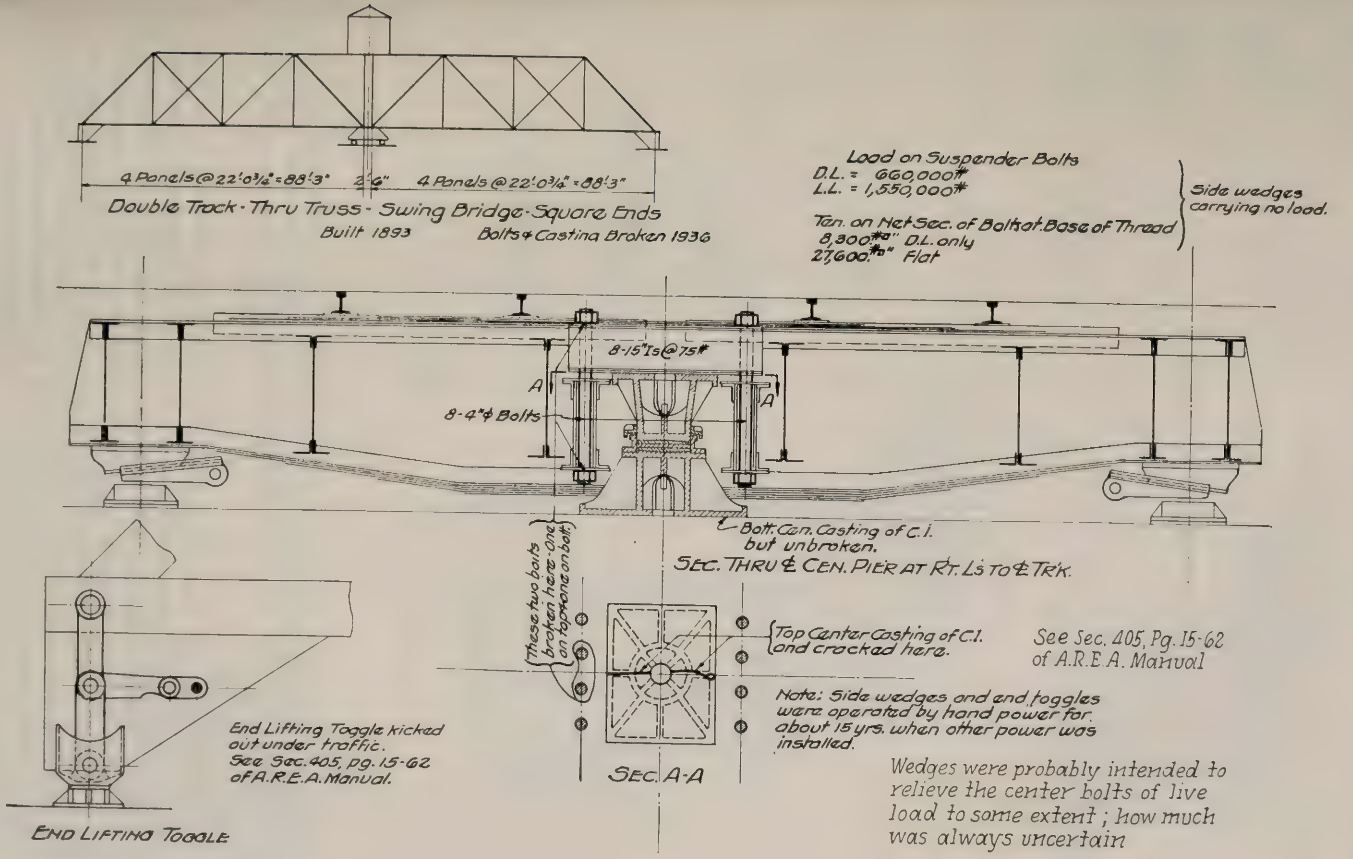

4 Panels @ 22'-0 3/4" = 88'-3"
2'-6"
4 Panels @ 22'-0 3/4" = 88'-3"
Double Track · Thru Truss · Swing Bridge · Square Ends
Built 1893
Bolts & Casting Broken 1936
Load on Suspender Bolts
D.L. = 660,000#
L.L. = 1,550,000#
Ten. on Net Sec. of Bolt at Base of Thread
8,300#/□" D.L. only
27,600#/□" Flat
Side wedges carrying no load.
8-15" Is @ 75#
A
A
8-4" ϕ Bolts
These two bolts broken here - One on top - one on bott.
Bott. Cen. Casting of C.I. but unbroken.
SEC. THRU ℄ CEN. PIER AT RT. ∠s TO ℄ TR'K.
Top Center Casting of C.I. and cracked here.
See Sec. 405, Pg. 15-62 of A.R.E.A. Manual
Note: Side wedges and end toggles were operated by hand power for about 15 yrs. when other power was installed.
End Lifting Toggle kicked out under traffic. See Sec. 405, pg. 15-62 of A.R.E.A. Manual.
SEC. A-A
END LIFTING TOGGLE
Wedges were probably intended to relieve the center bolts of live load to some extent; how much was always uncertain

FIG. 25

The foregoing is a description of the most interesting failures but a full realization of the failures can be obtained only by a study of the details shown on the drawings.

The committee has not attempted to discuss the remedies for these faulty details; the devising of such remedies is a difficult job.

Discussion of Principles

A brief discussion of some of the principles explaining the failures is given below:

Bridge designing, like most mechanical arts, developed from practical experience. Many long span bridges were built in early days without any knowledge of analytic mechanics. This was particularly true for stone arches and timber bridges. The advent of the metal structure and a heavy increase in the weight of locomotives made it necessary to consider bridges from the standpoint of analytic mechanics but these faulty details show that it is difficult to carry the principles and requirements of mechanics into the details.

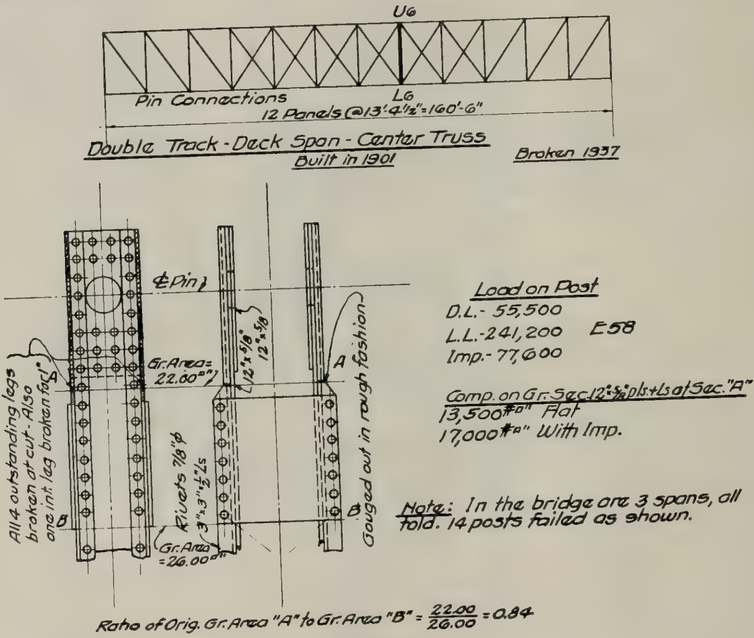

U6
Pin Connections
L6
12 Panels @13'-4½"=160'-6"
Double Track - Deck Span - Center Truss
Built in 1901
Broken 1937
℄ Pin
Gr. Area= 22.00□"
12"x5/8"
12"x5/8
A
A
B
B
All 4 outstanding legs broken at cut - Also one int. leg broken fac[?]
Rivets 7/8"φ
3"x3"x½"Ls
Gr. Area =26.00□"
Gouged out in rough fashion
Load on Post
D.L.- 55,500
L.L.-241,200 E58
Imp.- 77,600
Comp. on Gr. Sec. 12"x⅝" pls.+Ls at Sec. "A"
13,500#□" Flat
17,000#□" With Imp.
Note: In the bridge are 3 spans, all told. 14 posts failed as shown.
Ratio of Orig. Gr. Area "A" to Gr. Area "B" = 22.00/26.00 = 0.84

FIG. 26

About 85 years ago extensive experiments were made to determine the qualities of wrought iron and steel, with special reference to reversal and repetition of stress. Early formulas for allowable primary unit stresses took into account the relation between the minimum and maximum primary axial stresses. Later the idea was advanced that so long as primary stresses did not result in unit stress greater than the yield point of the material, it was not necessary to consider the effects of repeated stress or maximum and minimum stress except when reversal occurred. A typical specification to take care of such reversal is found in the present-day AREA Specifications—Art. 215.

However, no specifications take care of a pin connection subject to release or reversal of stress, with special reference to the effect of wear on the pin and pin hole. Fig. 13 and Fig. 30-B, referred to previously, are illustrations of the bad effects of a pin joint subject to release and reversals. The conclusion is warranted, that no pin connection should be subject to that kind of stress. It is remarkable that the eye-bars and pin through the main anchorage of the cantilever bridge, shown in Fig. 30-A, did not show any wear or looseness. As indicated before, the main anchors were continually under stress, there being no reversal or release whatever.

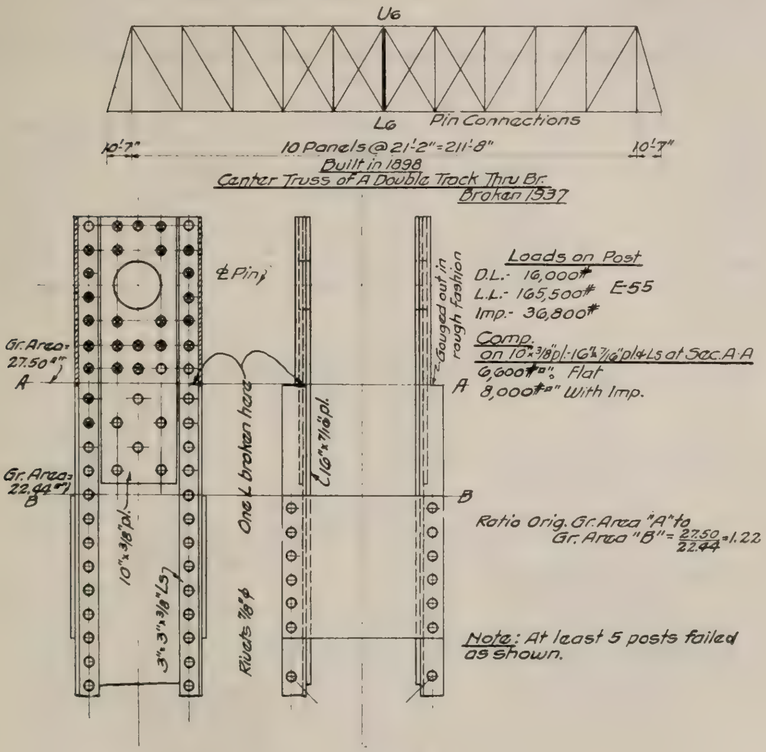


FIG. 27

The pin-connected counters of truss bridges loosen by wear of the pin and pin hole. This is one reason it is so necessary to have turnbuckles to take up the wear and slack.

Nearly all of the illustrations given are of bridges subject to heavy and frequent loading. For instance, consider the defective floor-beam connection cited previously in Fig. 29: This floor-beam connection was subject to about 182,000 applications of stress in a year; in 11 years, this would amount to 2,000,000 applications. The unit stress was far beyond the yield point and ultimate failure was bound to occur. It is remarkable that the detail lasted 32 years.

The other failures shown on the various drawings are also due to high unit stress, although the average stress on the net section through the section of failure is low. Recent experiments at the University of Illinois (see Bulletin 302) show that surface defects of the most minute character are "stress-raisers" and when a member with such defects is subject to a large number of repetitions of stress and possibly reversals of stress, failure will occur even though the average unit stress is low.

Bulletin 302 of the University of Illinois is well worth studying in considering the failure of bridge details shown in this report. Table 38 is particularly interesting, and is given here in part.

FATIGUE STRENGTH OF PLATES WITH MILL SCALE ON TWO SIDES AND WITH DRILLED HOLES BUT NO JOINTS

Kind of Steel (1)	*Spec. No.* (2)	*Stress Cycle thousands of lb. per sq. in. tension* (3)	*Cycles for Failure, thousands* (4)	*Fatigue Strength lb. per sq. in.* (5)
Carbon	B38–1	0 to 23.0	703	20,800
	B38–2	0 to 33.0	62	23,400
	B38–3	0 to 20.0	1332	19,300
			Average	21,200

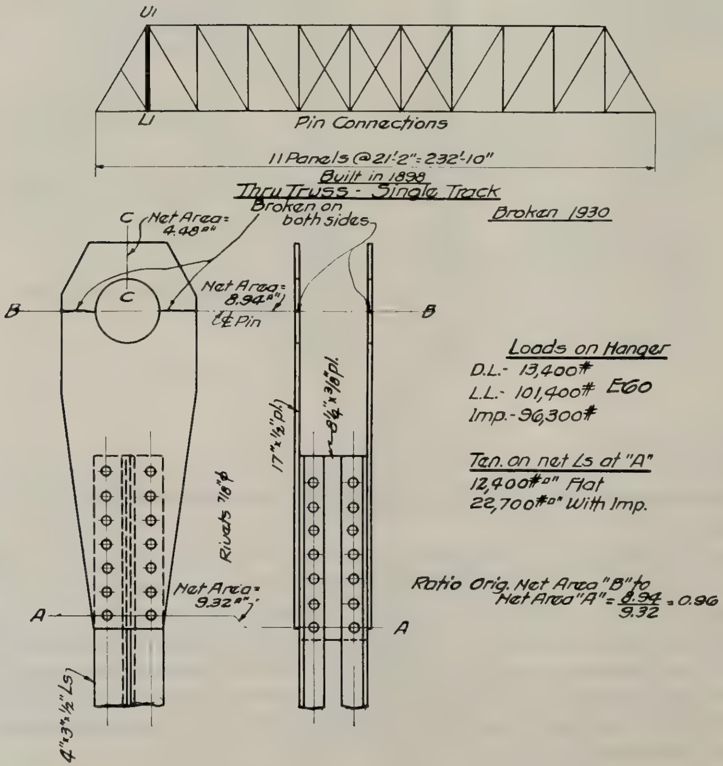


FIG. 28

This table shows results of tension tests on structural steel bars 5 in. wide, with a 1⅛-in. hole in the middle, the hole not filled. The bars were subjected to stresses varying from 0 to as high as 33,000 lb. per sq. in. on the net section through the hole. The average unit stress at failure for 2,000,000 repetitions of stress is 21,200 lb., which is much below the yield point of the material. Similar tests on bars without a hole, as shown in Table 37 (not given here), gave an average unit stress of failure of 30,300 lb. per sq. in. This average stress is about equal to the yield point of the material. The 30,300 lb. is about the elastic limit of the material, as would be obtained by testing a machined specimen and since, according to the elastic theory, material may be stressed an infinite number of times from zero to the elastic limit without failure, there must have been present mill scale material in which the stress greatly exceeded the elastic limit.

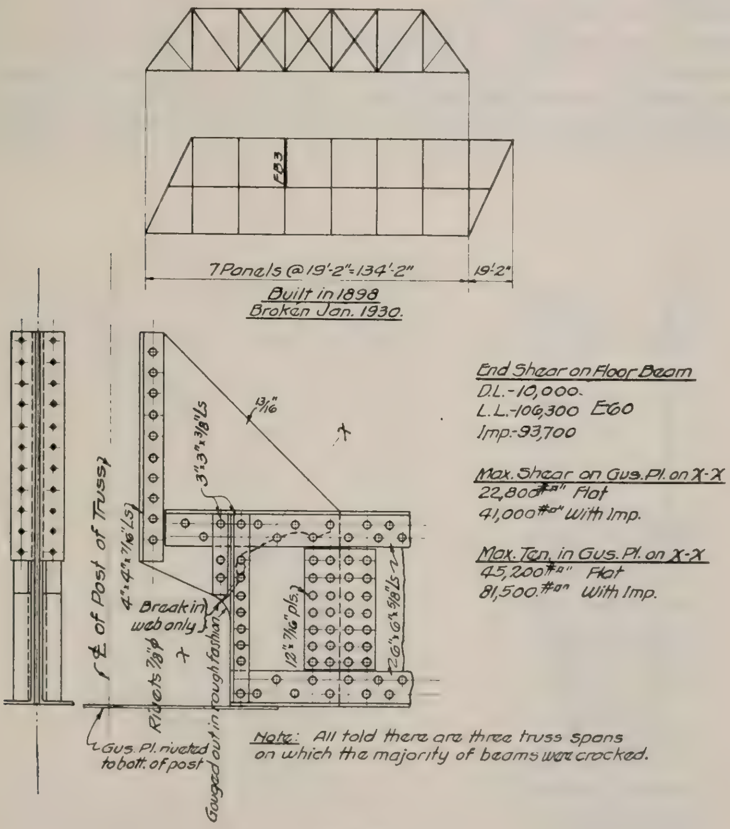


FIG. 29

These tests show that the unfilled hole in the test specimen of Table 38 lowered the average unit stress at failure from 30,300 lb. to 21,200 lb.

Table 26 of Bulletin 302 shows the fatigue strength of plates with holes filled with rivets. If there are three transverse rivets, the average fatigue strength is 26,700 lb. per sq. in., if there is only one rivet, the average is 23,800 lb. It appears, therefore, that a riveted joint has a higher average fatigue strength than a plate with an empty hole.

It seems obvious that the problem of designing a simple tension member with a hole in it has not yet been solved. Much laboratory effort has been put forth in years past to determine the buckling strength of columns, but the notion that the design of a tension member is a simple matter seems to have prevailed to this day.

This subject is being studied by Committee 15. Much time has been given, in the past, to determining what the net section of a tension member is; but, granting that this problem has been solved, there remains the determination of the proper average unit stress to use on the net section.

The present conception of what a test specimen of structural steel should be is largely an illusion. The specimen must be of a certain specific shape; it must be machined; hence it is largely free from stress-raising spots. Table 40 of Bulletin 302 gives a comparison of the results of experiments on material with mill scale and other imperfections to be found on material as it is actually used in a structure. It shows that, as

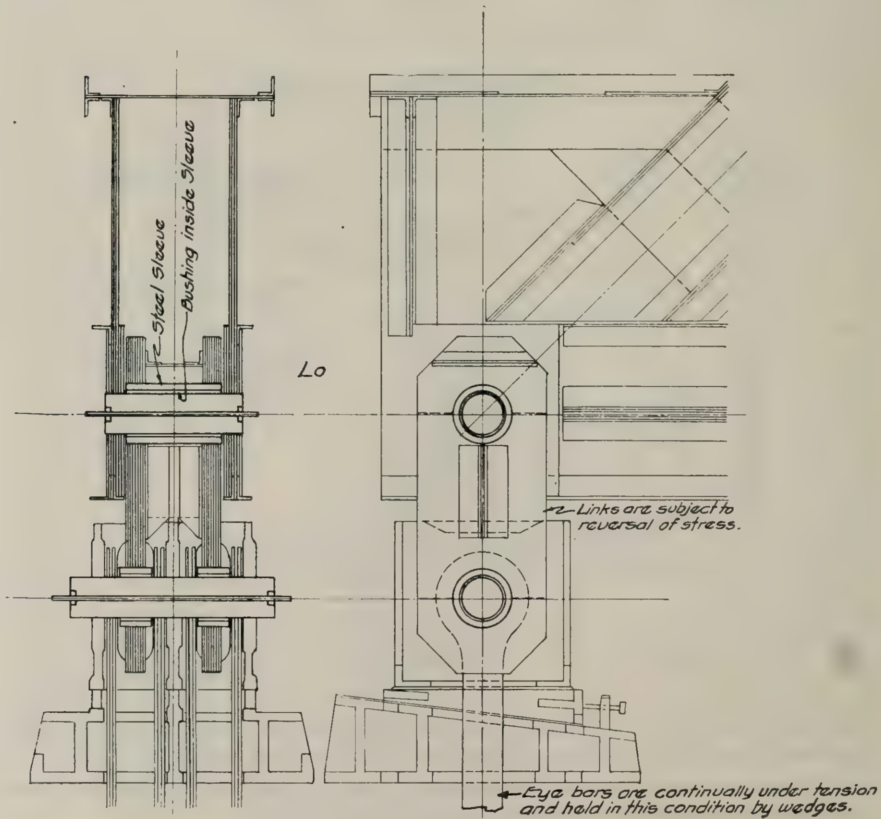
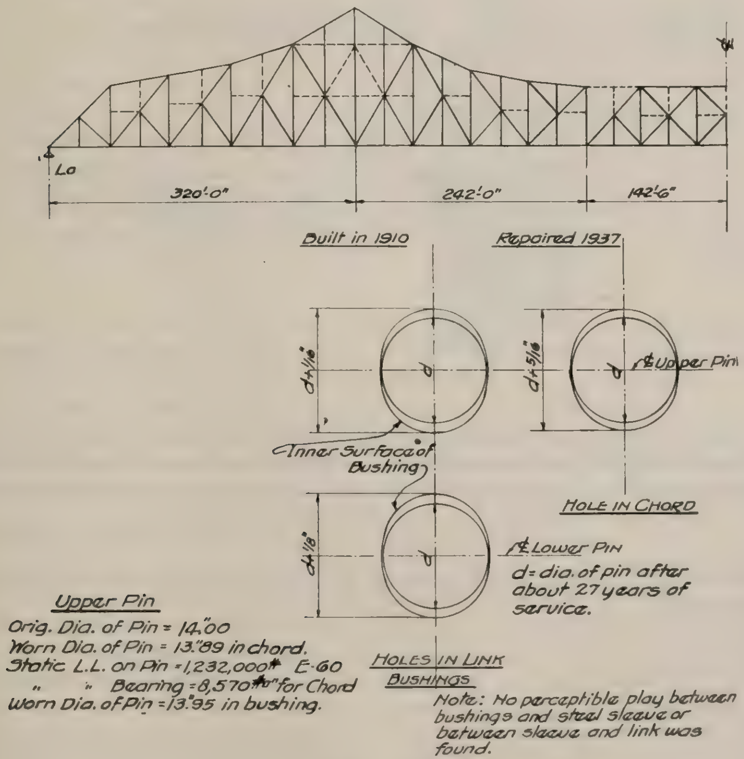

Steel Sleeve
Bushing inside Sleeve
Lo
Links are subject to reversal of stress.
Eye bars are continually under tension and held in this condition by wedges.

FIG. 30-A

compared with the machined test specimen, the strength of the material may be anywhere from two-thirds to less than one-half of the test-specimen results.

Actual experience with structures, as shown on the sketches, and also as clearly brought out in Bulletin 302, indicates that it is practically impossible to design a bridge and keep the maximum unit stress below the yield point of the material. No matter how carefully we design, we are always dealing with the average unit stress across any particular section of a tension member and parts of that section may be stressed beyond the yield point of the material. It appears that we must revert to the practice of early days of bridge engineering, and establish a relation between maximum and minimum average unit stress, together with a consideration of the probable number of applications of load. Obviously, for a bridge on a railroad line where the number of applications of stress is low over a period of many years, the designing stress may be higher than for a structure on a busy line where the applications of stress may run up to 2,000,000 or more in the course of fifteen or twenty years. The members of a bridge are not machined to remove mill scale or other defects and, furthermore, are not polished.

The question of proper rating of old bridges now requires a more careful study and, more important, careful field inspection.



d = dia. of pin after about 27 years of service.

Upper Pin
Orig. Dia. of Pin = 14.00"
Worn Dia. of Pin = 13.89" in chord.
Static L.L. on Pin = 1,232,000# E-60
" " Bearing = 8,570#/□" for Chord
Worn Dia. of Pin = 13.95" in bushing.

Note: No perceptible play between bushings and steel sleeve or between sleeve and link was found.

FIG. 30-B

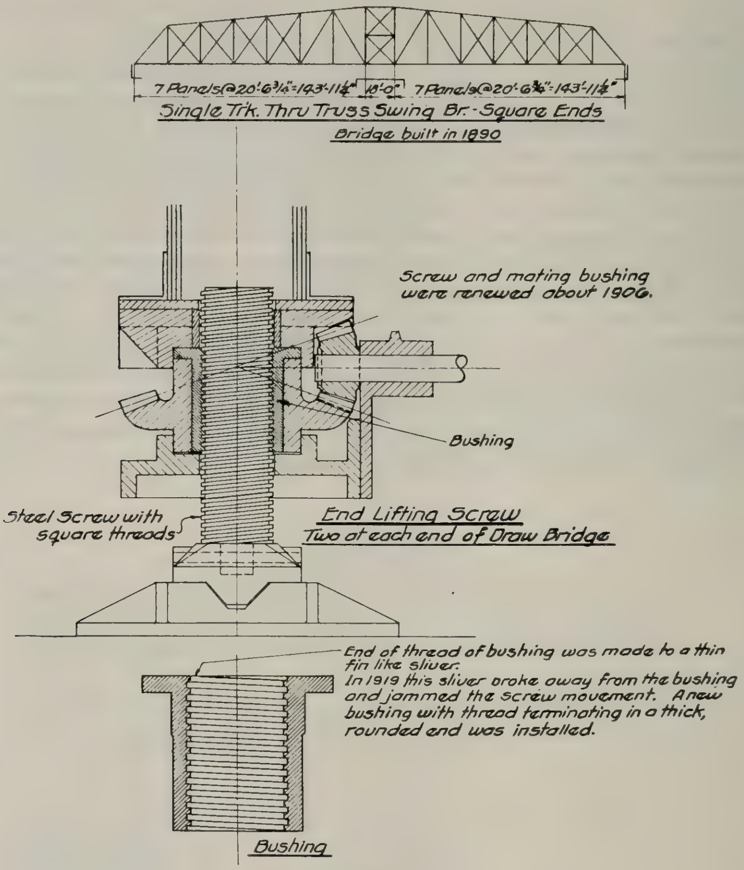

7 Panels@20'-6¾"=143'-11¼"
18'-0"
7 Panels@20'-6¾"=143'-11¼"
Single Trk. Thru Truss Swing Br.-Square Ends
Bridge built in 1890
Screw and mating bushing were renewed about 1906.
Bushing
Steel Screw with square threads
End Lifting Screw
Two at each end of Draw Bridge
End of thread of bushing was made to a thin fin like sliver.
In 1919 this sliver broke away from the bushing and jammed the screw movement. A new bushing with thread terminating in a thick, rounded end was installed.
Bushing

FIG. 31

Bulletin 302 and this exhibition of faulty details, it seems, confirm each other. Here the field and the laboratory have come together in agreement as regards the general principles underlying the failures of details. We must beware of repetition of live load stress, in particular, where there is a small dead load or none at all.

This report is presented as information with the recommendation that the subject be discontinued.

Report of Special Committee on Waterproofing of Railway Structures

J. A. LAHMER, *Chairman*	A. C. IRWIN	F. P. TURNER
F. E. BATES	L. H. LAFFOLEY	L. W. WALTER
G. E. BOYD	F. J. PITCHER	H. T. WELTY
C. H. CHAPIN	G. E. ROBINSON	C. A. WHIPPLE
A. C. COPLAND	A. L. SPARKS	O. G. WILBUR

Committee.

To the American Railway Engineering Association:

Your committee respectfully reports on its assignments as follows:

1. Revision of Manual

Change rate of elongation per minute specified for ductility test at 40 degrees F. of asphalt for saturant and mopping above ground (Section 202 in the Manual), from 1 cm. to ¼ cm., so same will read:

(g) Ductility at 40°F. (4°C.): elongation at rate of ¼ cm. per minute—not less than 4 cm.

This rate means an elongation of ¼ cm. per minute in sample (3 cm. long) used in ASTM test. This reduction is recommended because the committee believes that it will lessen the possibility of premature rupture due to mechanical jar or other cause, in what is considered a delicate test, and that the proposed rate of elongation is in excess of rate of elongation which will be normally developed in actual service.

Change the first sentence of paragraph 7, Section 301, to read as follows:

Coal tar pitch shall not be heated above 250 degrees F., except that under unusual conditions, such as low temperature or long haul, it may be heated to a maximum of 325 degrees F., to facilitate mopping. Asphalt shall not be heated above a temperature of 350 degrees F.

Section 212 of the Manual covers plastic cement having an asphalt base. It is recommended that this section be revised to include plastic cement having a coal tar base. The proposed new section is given in Appendix A.

The present specifications for membrane waterproofing provide for asphalt mastic protective cover. It is recommended that certain changes be made in the Manual as indicated in Appendix B, in order to make provision for coal tar pitch mastic protective cover, and to make the requirements for fine mineral aggregate more definite.

2. Waterproofing and Dampproofing of Railway Structures

Further consideration has been given to the request made by the ASTM in November, 1937, that the AREA comment on certain ASTM revised specifications covering bituminous materials for waterproofing, of which the most important one is specification D—449–37T, Asphalt for saturant and mopping in connection with membrane waterproofing for use above ground. The ASTM does not seem disposed to raise the requirements in its tentative specification D—449–37T, and the committee does not deem it advisable to lower any of the requirements in the specifications in the Manual. Information has been received that asphalt from Mexican crude oil, which will meet the AREA specifications, is again being offered in the United States, and there is reason to believe that asphalt from domestic crude, which will meet the requirements of the

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Bulletin 415, January, 1940.

present AREA specifications will be available, if the rate of elongation in the test for ductility at 40 degrees F. is reduced from 1 cm. per minute to ¼ cm. per minute.

The Special Committee on Waterproofing of Railway Structures,

J. A. Lahmer, *Chairman.*

Appendix A

212. Plastic Cement

1. Plastic cement shall be composed of (a) semi-solid asphalt or (b) refined coal tar, dissolved in a suitable volatile solvent and stiffened with a mineral filler consisting essentially of short fiber asbestos.

2. The asphalt forming the base of plastic cement shall be either a fluxed native asphalt or a straight steam-refined asphaltic petroleum residual that has not been oxidized or blown, the pure bitumen of which shall meet the following minimum requirements:

Penetration at 77° F., 100 grams, 5 seconds	30
Ductility at 77° F., 5 cm. per minute	100 cm.

It shall be free from water, oxidized petroleum, residuals from the cracking process, sludge asphalt, tar or pitch products, or derivatives thereof.

3. Plastic cement shall be a smooth uniform mixture, not thickened or livered, and showing no separation which cannot be easily overcome by stirring.

It shall yield not less than 70 percent of nonvolatile matter when 10 grams are heated in an oven at 105 to 110 degrees F. (221 to 230 degrees C.) for 24 hours.

It shall yield on ignition not less than 15 percent or more than 45 percent of ash.

4. Plastic cement shall be of such consistency that it can be spread readily with a trowel without drawing or pulling, or can be extruded through a suitable nozzle under a pressure of not more than 5 pounds per square inch at a temperature of 50 degrees F.

5. When applied in a layer 1/16 inch to ⅛ inch thick on the material on which it is to be used, plastic cement shall set within 24 hours to a tough plastic coating, free from blisters.

6. A patch of plastic cement 1/16 inch to ⅛ inch thick, applied on the material on which it is to be used, then dried 60 minutes in a well ventilated room, and then held in a vertical position while exposed to a temperature of 140 degrees F. for 5 hours, shall not sag more than ¼ inch or slip or blister and shall show no appreciable absorption of the cement by the material to which it is applied.

7. A patch of plastic cement 1/16 inch to ⅛ inch thick, applied on the material on which it is to be used, then dried for 60 minutes in a well ventilated room, then exposed to a temperature of 140 degrees F. for 5 hours, and then cooled to a temperature of 32 degrees F. and bent quickly through 180 degrees over a mandrel 1 inch in diameter, shall not crack or separate from the material to which it has been applied.

8. A patch of plastic cement 1/16 inch to ⅛ inch thick, applied on the material on which it is to be used, then dried for 72 hours in a well ventilated room, then exposed to a temperature of 140 degrees F. for 5 hours, and then exposed to a temperature of 32 degrees F. for one hour, shall remain plastic and adhere well to the material to which it has been applied.

Appendix B

Mastic for Protective Cover

213. Asphalt Mastic

Present Form

3. Fine mineral aggregate shall be well graded washed sand or crushed stone that will pass a No. 10 screen. It shall be free from soft particles and organic matter.

Proposed Form

3. Fine mineral aggregate shall be well graded washed sand or crushed stone that will meet the following requirements:

Passing a 100-mesh sieve	not more than 6 percent
Passing a 40-mesh sieve	40–80 percent
Passing a 10-mesh sieve	not less than 90 percent

Insert new Section 213–½ Coal-tar Pitch Mastic:

213½. Coal-Tar Pitch Mastic

Coal-tar pitch mastic shall be poured in place. It shall be composed of coal-tar pitch mixed with mineral filler and mineral aggregates.

1. Coal-tar pitch for mastic shall meet the following requirements:

(a) Specific Gravity at 70°/77°	not less than 1.20
(b) Softening (ring and ball method)	150° F. to 170° F.
(c) Penetration at 115° F., 50 grams, 5 sec.	not more than 120
Penetration at 77° F., 100 grams, 5 sec.	15 to 35
Penetration at 32° F., 200 grams, 60 sec.	not less than 4
(d) Solubility in Carbon disulphide	63 percent to 78 percent
(e) Ash	not more than 3 percent

2. Coarse mineral aggregate shall meet the requirements of Section 213 (2).
3. Fine mineral aggregate shall meet the requirements of Section 213 (3).
4. Mineral filler shall meet the requirements of Section 213 (4).

Revise list in Section 302 (1)—Protective cover, by adding the following and relettering present (c) and (d):

(c) A layer of poured-in-place coal-tar mastic not less than 1½ inches thick.

Revise Section 302 (3) and (4) by adding "by weight" after "proportions".

Insert new Sections 302 (5) to read:

5. Coal-tar pitch and mineral aggregates shall be mixed in the following proportions, by weight, varied within specified limits, to give a mastic of the greatest density and stability.

Coal-tar pitch meeting requirements of Section 213½ (1)	12 percent to 16 percent
Coarse mineral aggregate meeting requirements of Section 213 (2)	30 percent to 40 percent
Fine mineral aggregate meeting requirements of Section 213 (3)	30 percent to 40 percent
Mineral filler meeting requirements of Section 213 (4)	15 percent to 20 percent

Change first part of Section 302 (5) to Section 302 (6) and revise to read:

6. The asphalt, or asphalt and asphalt mastic cake, or coal-tar pitch shall be melted in the kettle, heating to 250° F. for coal-tar pitch mastic and to 350° F. for asphalt mastic. The aggregate shall be mixed and heated to 212° F.–275° F. and then placed in the kettle containing melted bitumen. The ingredients shall be well mixed with iron stirring rods until all pieces of the aggregate are covered with bitumen, and the aggregates are distributed uniformly throughout the mixture. During the mixing process care shall be taken to avoid local overheating of the mixture, the temperature of which shall generally be maintained between 300° F. and 375° F. and shall at no time exceed 400° F.

Note.—All equipment used in preparing and placing mastic shall be thoroughly clean, with special precautions to avoid mixing asphalt and coal-tar materials.

Change the remainder of Section 302 (5) to Section 302 (7).

7. After the mastic has been mixed it shall be poured into place while hot. It shall be placed in layers not more than ¾ inch thick. The thickness shall be gaged by wooden strips held in position by suitable weights. The layers shall be brought to the required thickness with wooden spreaders and floats, and shall lap joints not less than 6 inches. The top layer shall be finished to the required grade and to a smooth surface. As soon as the top layer of the mastic is finished, it shall be given a mopping of hot bitumen of the same kind as used in the mastic, sanded to a walking surface while hot.

Section 6 and subsequent sections to be renumbered.

Report of Committee 11—Records and Accounts

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H. D. Barnes
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B. A. Bertenshaw
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C. P. Richardson
C. K. Smith
James Stephenson
H. J. Strobel
D. C. Teal
H. C. Wertenberger
A. P. Weymouth
Louis Wolf
Committee.

To the American Railway Engineering Association:

Your committee respectfully reports on the following subjects:

1. Revision of Manual (Appendix A).

2. Bibliography on subjects pertaining to records and accounts (Appendix B). Progress report.

3. Office and drafting room practices (Appendix C). Partially complete with recommended conclusions for publication in the Manual.

4. Maintenance of way reports and records (Appendix D). Complete with recommended conclusions for publication in the Manual.

5. Construction reports and records (Appendix E). Partially complete with recommended conclusions for publication in the Manual.

6. Valuation (Appendix F). Progress report.

7. Changes in or revisions of I.C.C. Classification of Accounts (Appendix G). Progress report.

8. Methods for avoiding duplication of reports and for simplifying and co-ordinating work under the requirements of the I.C.C. and other public authorities (Appendix H). Progress report.

The Committee on Records and Accounts,
C. A. Knowles, *Chairman.*

Appendix A

(1) Revision of Manual

D. E. Field (chairman, subcommittee), D. L. Avery, W. F. Cummings, J. H. Hande, R. J. Herring, W. R. Kettenring, E. M. Killough, P. R. Leete, Henry Lehn, D. O. Lyle, E. W. Metcalf, A. T. Powell, H. J. Stroebel.

All forms with their accompanying text pertaining to the committee's assignments appearing either in the Manual or Proceedings have been reviewed. The review disclosed that the forms tabulated below had been approved for publication in the Manual, but had never appeared therein. Arrangements have now been made for the inclusion of these forms in the Manual.

Bulletin 415, January, 1940.

Form No.	Description	Proceedings Vol.	Page
1120	(Revised) Bridge Inspection Report—Masonry, Steel Bridges and Trestles	35	611
1120–A	Bridge Inspection Report—Wood Boxes & Pipe Culverts	35	612
1120–B	Bridge Inspection Report—(Summary)	35	613
1146	Foreman's Daily Report of Work Train Performance	31	897
1147	Conductor's Daily Report of Work Train Performance	31	899
1148	Report of Quantities in Completed Work	38	556
1149	Cost of Property Retired	38	566
1150	Roadway Machine Record	38	559
1151	Construction Report of Timber Trestles	38	558
1152	Construction Report for Wood Boxes & Pipe Culverts	38	560
1153	Construction Report for Concrete Trestles, Arches & Boxes	38	561
1154	Construction Report for Steel Bridges	38	562
1155	Report of Rail Change	38	563

Form 1120, revised, should be substituted for present form 1120, and this is so recommended, since the revised form more adequately covers the subject.

Appendix B

(2) Bibliography On Subjects Pertaining to Records and Accounts

E. V. Braden (chairman, subcommittee), H. N. Halper, C. D. Johnson, C. P. Richardson, C. K. Smith, D. C. Teal, A. P. Weymouth.

The subcommittee has followed the practice of previous years in compiling the bibliography for the current year. Peroidicals likely to contain important articles pertaining to railway Records and Accounts were systematically reviewed, also reference lists of new books and pamphlets for any items of special usefulness or interest to members of the Association. The following compilation is submitted as the result of such a bibliographical review for the period from November 1, 1938, to November 1, 1939.

Bibliography

Books

1. Science of Valuation and Depreciation—By Edwin B. Kurtz, E.E., Ph.D. 221 pp. 120 Illustrations. The Ronald Press Company, Publishers, 15 East 26th Street, New York. The author seeks to co-ordinate engineering data of service life with practical requirements of accounting. He applies mortality laws of physical property in estimating and accounting for depreciation on a scientific basis. Provides physical property life experience tables, life expectancy curves, service life characteristic charts, etc.

2. Engineering Terminology—By Victor J. Brown and Delmar C. Runner. Gillette Publishing Company, Chicago. Enlarged second edition defines accepted meaning of word or phrase as used in any particular branch of engineering. All engineering fields are covered and several appendices include standard map symbols.

3. Depreciation Principles and Methods—Report presented to annual convention of the National Association of Railroad and Utilities Commissioners at New Orleans, La., November, 1938. Published by the State Law Reporting Co., New York. The report is of significance and wide interest to engineers in railway and utility fields.

4. Technical Drawing—By Giesecke, Mitchell & Spencer, Published by MacMillen Co. Copyright 1933–36. Reprinted September 1937. A text book on the subject of mechanical drawing—machines.

Papers

1. Federal Valuation of Railroads—By Edwin F. Wendt, 59 pp. Published by the American Railway Engineering Association, in Bulletin No. 412, Sept.–Oct., 1939. This paper concisely and clearly traces the developments of the federal valuation of railroads: —the organization created to perform the task, the progress of the inventory field and office work, pricing and completing the engineering, land and accounting reports, conferences and hearings on protested items, price levels, the effect on the work of subsequent amendments to the valuation act itself and the total cost of the completed work. Tentative values, final valuations, final (single sum) values, other values and elements of value are discussed by the author, who was a member of the original engineering board.

2. American Standard—Graphical Symbols for Drawings—Published by the American Standards Association, 29 West 39th Street, New York, Bulletin ASA–Z–14.2—1935.

3. American Standard—Drawing and Drafting Room Practices—Published by the American Standards Association, 29 West 39th Street, New York, N. Y., Bulletin ASA–Z–14.1—1935.

4. U. S. Treasury, Bureau of Internal Revenue, Bulletin No. 22, dated May 29, 1939. —Announces the ruling that retirement loss sustained on account of an overhead highway bridge constructed at the expense of a publicly financed highway-railroad grade project, can be deducted from income for tax purposes.

Appendix C

(3) Office and Drafting Room Practices

D. C. Teal (chairman, subcommittee), D. L. Avery, B. A. Bertenshaw, D. E. Field, A. T. Hopkins, C. D. Johnson, W. M. Ludolph, E. W. Metcalf, H. C. Wertenberger, A. P. Weymouth.

The following subjects were assigned for study and report:

(a) Methods of folding and punching drawings.
(b) Scales of reduction and enlargement.
(c) Width of rolls of paper and cloth.
(d) Sizes of drafting equipment and tools.
(e) Specifications of materials to be used for drawings and drafting.
(f) Standard system for filing drawings.

Reports covering the first four subjects are submitted herewith. Your committee reports progress in study of the last two and expects to complete them next year.

In general, standards and practices recommended here are those of the majority of users as indicated by replies to a questionnaire submitted to 58 Class I railroads. Although it is impractical to set up results of this questionnaire in tabular form, the findings have been carefully abstracted and when consistent are introduced into the reports as supporting data for the conclusions and recommendations.

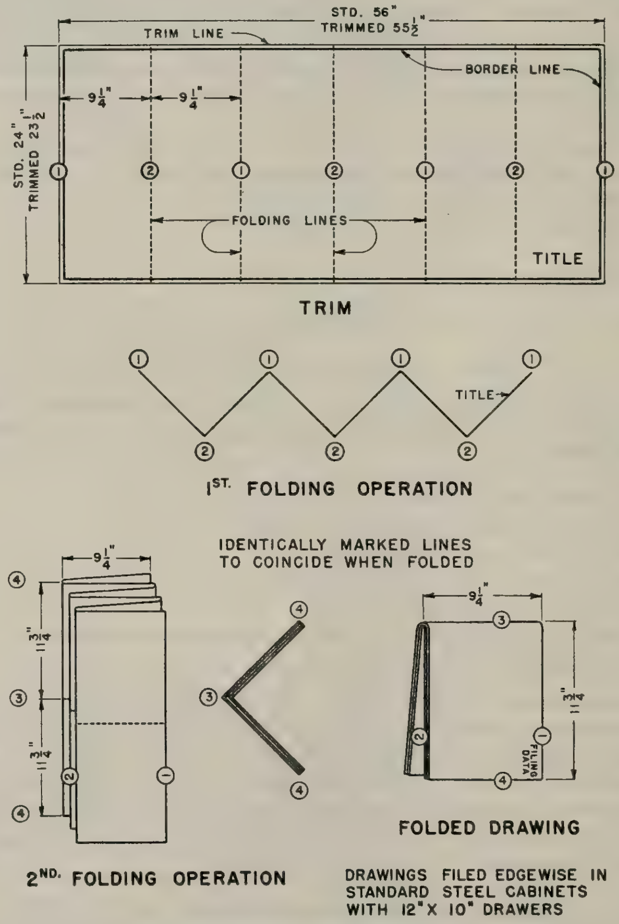
(a) Methods of Folding and Punching Drawings

A report on this subject was made at the March, 1939, convention and published in Proceedings, Vol. 40, pages 444 to 448 as information. The figures illustrating recommended folding methods have been revised to include information developed by further study and are again submitted to the Association. Your committee recommends their adoption and publication in the Manual as pages 11–72.1 and 11–72.2, together with the following introductory text:

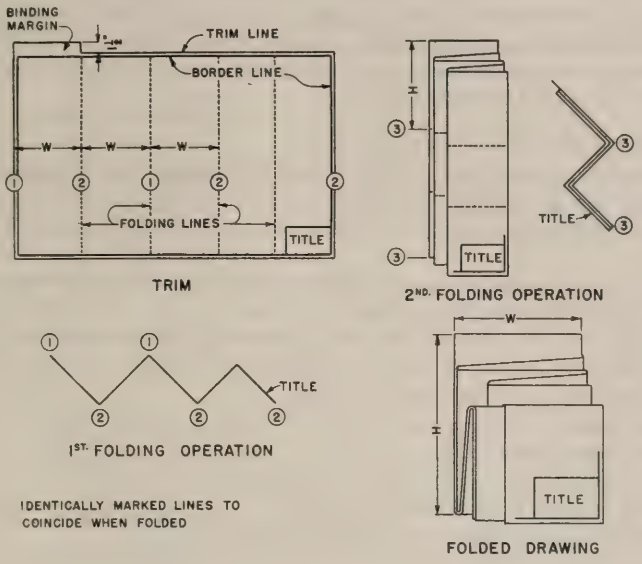
METHODS OF FOLDING DRAWINGS

It is frequently necessary in office and drafting room work to fold and otherwise prepare drawings for storage in filing cases, attachment to correspondence files, or for binding in special reports. The methods here illustrated have been found best suited to railway office and drafting room requirements.

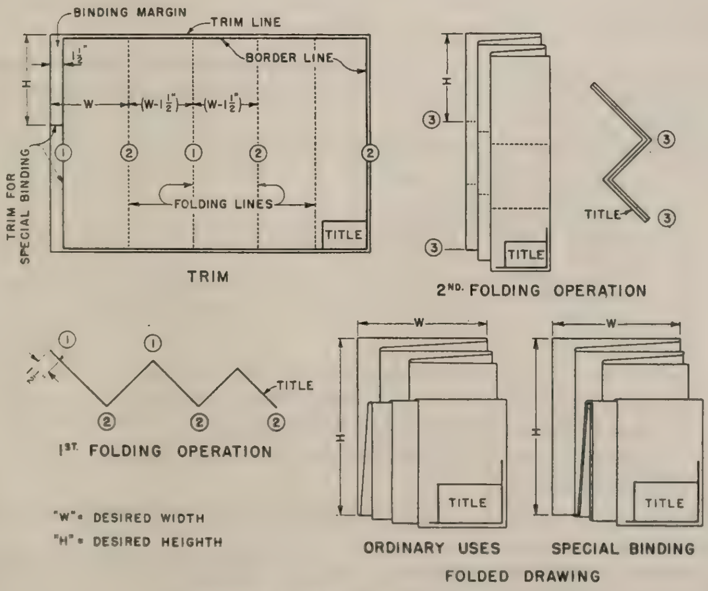
It is recommended that the subject be discontinued.



RECOMMENDED METHOD OF FOLDING VALUATION MAP PRINTS FOR STORAGE IN FILING CABINETS



BINDING MARGIN AT TOP



BINDING MARGIN AT LEFT SIDE

RECOMMENDED METHODS OF FOLDING DRAWINGS

(b) Scales of Reduction and Enlargement

A report on this subject was made at the March, 1939, convention under the heading, Reduction and Enlargement of Drawings. After reviewing the subject the committee concludes that the report submitted in 1939 adequately covers the assignment and recommends that the subject be discontinued.

(c) Width of Rolls of Paper and Cloth

Information received from 37 Class I railroads indicates that it is common practice to carry only one or two sizes of drawing paper and tracing cloth in stock, widths and lengths of rolls being governed by the dimensions of the larger drawings and by current needs.

A table of recommended sizes for railway drawings is shown in the Manual on pages 11–71 and 11–72. The sizes range from 4 by 7-in. to 34 by 44-in. With consideration given to these sizes as well as to other factors involved, your committee recommends the following widths as best suited for general railroad drafting room uses:

Detail drawing paper—36 and 42-in. rolls.
Tracing cloth—24, 30, 36, and 42-in. rolls.
Tracing paper—36-in. rolls.
Cross section paper and cloth—20 to 24-in. rolls.
Profile paper and cloth—20 to 24-in. rolls.
Blue or colored line print paper—24, 36 and 42-in. rolls.
Lengths of rolls in each case should be governed by current needs.

The report on widths of drawing paper and cloth is submitted as information with recommendation that the subject be discontinued.

(d) Sizes of Drafting Equipment and Tools

As a rule the draftsman owns his own drawing instruments while the larger items of drafting room equipment and special drafting appurtenances are furnished by the railway company.

The draftsman usually provides the following items:

1. Set of drawing instruments consisting of:
   (a) One small and one medium size ruling pen.
   (b) Compass with pen and pencil attachments and lengthening bar.
   (c) Divider.
   (d) Bow pencil.
   (e) Bow pen.
   (f) Bow divider.
2. A collection of transparent celluloid triangles consisting of:
   (a) Medium sized 45-deg. and 30-deg.—60-deg. triangles.
   (b) Small 45-deg. and 30-deg.—60-deg. triangles.
   (c) Lettering triangle or guide line device.
   (d) Irregular curve.
3. Engineers and architects scales (triangular or flat) with divisions to suit work requirements of the office.
4. T-Square (when drafting machine or parallel ruling devices are not available).
5. Protractor with divisions reading to ½ deg.
6. Slide rule.
7. Miscellaneous drawing board items such as—erasing shield, desk knife, desk brush, thumb tack lifter, and other equipment of a personal nature.

To obtain the most satisfactory results, it is believed advisable, and in the end more economical, to purchase drawing instruments of good quality. In this connection, probably the best criterion to follow is the reputation of the maker.

Drafting room equipment and special instruments ordinarily furnished by the company consist of:

1. Drawing tables with lamps and stools.
2. Filing cabinets for plans.
3. Blueprinting and reproduction equipment.
4. Parallel ruling or drafting machine devices.
5. Railroad curves.
6. Suitable steel straight edges.
7. Large sized triangles and T-square.
8. 24-in. scales.
9. Beam compass.
10. Pantograph.
11. Planimeter.
12. Proportional dividers.
13. Lettering templets and scribes.
14. Large protractor with vernier.
15. Adding and calculating machines.
16. Electric erasing machine.
17. General office equipment such as book cases, shears, eyelet punch, stapling machine, pencil sharpener, etc.

Here again, the general effectiveness of the drafting room is influenced by the completeness with which the office is equipped and by the kind and quality of this equipment. It is recommended good practice to furnish equipment and supplies of good quality with selection limited to reputable manufacturers.

Any text book on drawing will describe the advantages and disadvantages of various types of drawing instruments and this report does not attempt to cover such details. However, the selection of drawing tables involves several principles that are not found in the standard drawing text books and which your committee believes are important enough to mention.

Drawing Tables:—The varied demands of railway work necessitate use of large drawing tables. Questionnaire answers indicate that sizes range from 2½ ft. wide by 3½ ft. long to 4 ft. wide by 8 ft. long with the great majority using the 3 ft. by 6 ft. to 3½ ft. by 7 ft. dimensions. A few listed special boards of 10, 15 and 20-ft. lengths for use in connection with long profiles. The three most generally used types may be classified as:

1. Drawing boards supported at ends on "X" trestles or horses.
2. Wood frame tables with drawers and rigid non-adjustable tops.
3. Steel frame tables with drawers and adjustable tops.

Some railroads use all three types, others mention only the first two. The No. 1 or board-on-trestle type is ordinarily found in field construction offices and is held for emergency uses while regular table types are provided for the permanent general office drafting rooms. An extra table is sometimes furnished for the convenient handling of reference prints. This need not be very large and can be designed so as to fold up when not in use. Although very convenient at times, the advisability of having such auxiliary tables depends upon space limitations and the general nature of the work.

Questionnaire answers indicate that approximately 25 percent of the railroads use the patented parellel ruling and drafting machine devices while the remaining 75 percent rely on the T-square and straight edge methods.

Steel frame tables are, of course, preferred to the wooden ones which soon lose their rigidity. An arrangement for tilting the top is desirable for certain kinds of work.

It is recommended that when new or replacement drawing table equipment is to be ordered, consideration be given to steel frame tables with the type of parallel ruling device most suitable to the class of work involved, as these items will do much to encourage efficient drafting work.

The report on sizes of drafting equipment and tools is presented as information with the recommendation that the subject be continued.

Appendix D

(4) Maintenance of Way Reports and Records

H. L. Restall (chairman, subcommittee), Anton Anderson, D. L. Avery, E. V. Braden, W. F. Cummings, C. D. Johnson, W. M. Ludolph, W. S. McFetridge, O. M. Miles, A. T. Powell, C. K. Smith, D. C. Teal, A. P. Weymouth.

The committee has completed the preparation of the forms for Maintenance of Way Statistics in accordance with its assignment. There is now presented as Exhibit 1, a chart showing the title of the forms and references to the Proceedings. It is recommended that the chart be published in the Manual as page 11–44.1.

Appendix E

(5) Construction Reports and Records

E. M. Killough (chairman, subcommittee), Anton Anderson, E. V. Braden, V. H. Doyle, C. C. Haire, J. H. Hande, A. T. Hopkins, W. S. MacCulloch, W. S. McFetridge, O. M. Miles, C. P. Richardson, Jas. Stephenson, H. J. Stroebel, Louis Wolf.

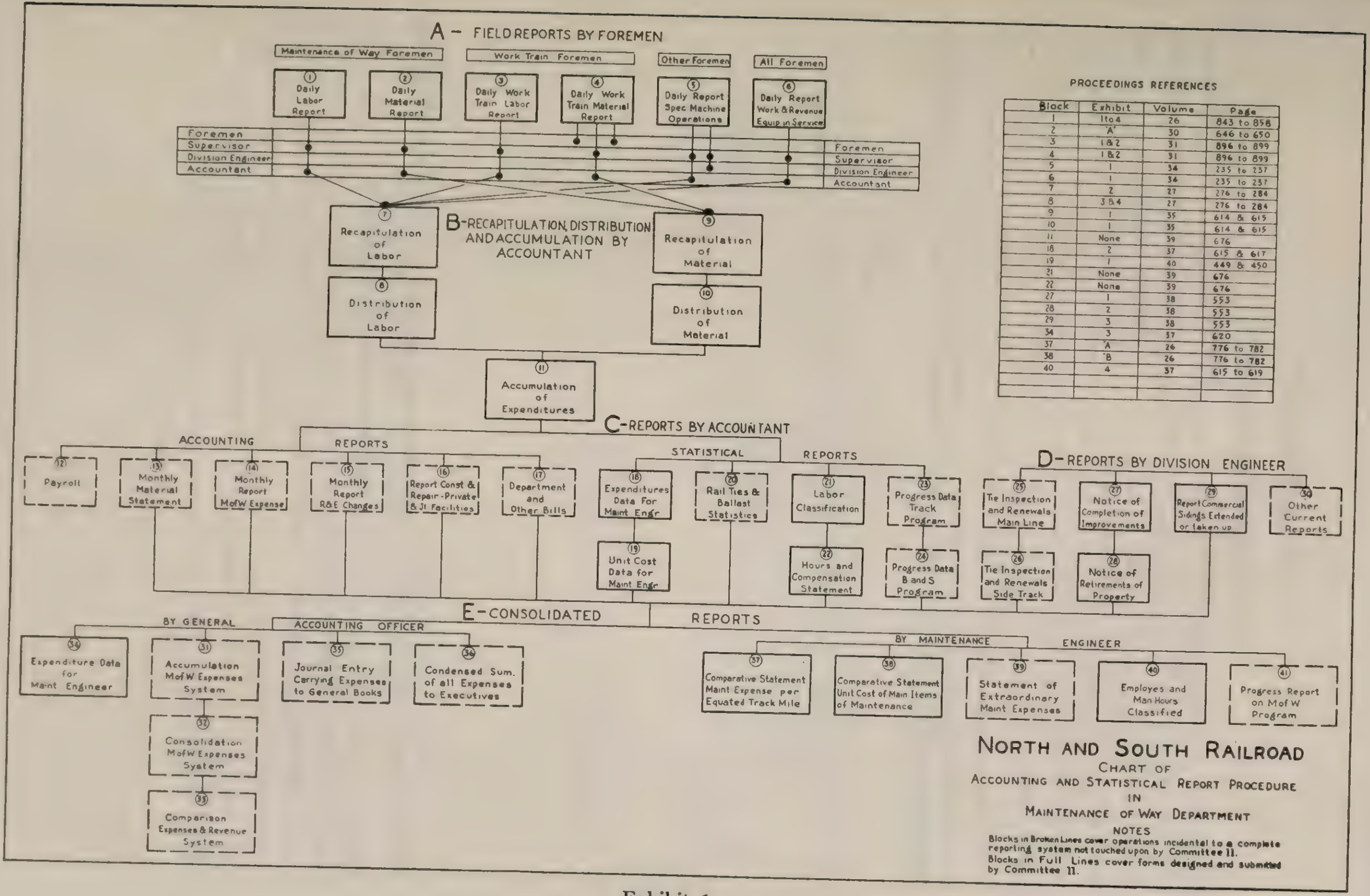
1. Bridge Forms

The committee has prepared forms for recording descriptive information relative to railroad and overhead bridges, including both those constructed at the sole expense of the carrier and those constructed in whole or in part with public funds. It was the opinion of the committee that such forms should be designed because during recent years many overhead bridges have been constructed with public funds and unless provision is made therefor, the details may not be readily available in the future.

Three forms are presented herewith: (Exhibit 2) descriptive information and sketch of an Account 6 railroad bridge; (Exhibit 3) similar data for an overhead highway bridge, and (Exhibit 4) a form to be used for recording the final construction quantities, which covers both kinds of structures. If a carrier is interested in descriptive matter only, the quantity sheet may be omitted.

2. Numbering of Bridges

The committee has given consideration to the method recommended for the identification and designation of bridges shown in the Proceedings, Vol. 38, page 554, and has revised the material for publication in the Manual. It is recommended that the matter on the upper portion of page 461 be so published as page 11–30.1.


A – FIELD REPORTS BY FOREMEN
Maintenance of Way Foremen
Work Train Foremen
Other Foremen
All Foremen
① Daily Labor Report
② Daily Material Report
③ Daily Work Train Labor Report
④ Daily Work Train Material Report
⑤ Daily Report Spec Machine Operations
⑥ Daily Report Work & Revenue Equip in Service
Foremen
Supervisor
Division Engineer
Accountant
B-RECAPITULATION, DISTRIBUTION AND ACCUMULATION BY ACCOUNTANT
⑦ Recapitulation of Labor
⑧ Distribution of Labor
⑨ Recapitulation of Material
⑩ Distribution of Material
⑪ Accumulation of Expenditures
C-REPORTS BY ACCOUNTANT
ACCOUNTING REPORTS
STATISTICAL REPORTS
⑫ Payroll
⑬ Monthly Material Statement
⑭ Monthly Report MofW Expense
⑮ Monthly Report R&E Changes
⑯ Report Const & Repair-Private & Jt Facilities
⑰ Department and Other Bills
⑱ Expenditures Data For Maint Engr
⑲ Unit Cost Data for Maint Engr
⑳ Rail Ties & Ballast Statistics
㉑ Labor Classification
㉒ Hours and Compensation Statement
㉓ Progress Data Track Program
㉔ Progress Data B and S Program
D-REPORTS BY DIVISION ENGINEER
㉕ Tie Inspection and Renewals Main Line
㉖ Tie Inspection and Renewals Side Track
㉗ Notice of Completion of Improvements
㉘ Notice of Retirements of Property
㉙ Report Commercial Sidings Extended or taken up
㉚ Other Current Reports
E-CONSOLIDATED REPORTS
BY GENERAL ACCOUNTING OFFICER
BY MAINTENANCE ENGINEER
㉞ Expenditure Data for Maint Engineer
㉛ Accumulation MofW Expenses System
㉜ Consolidation MofW Expenses System
㉝ Comparison Expenses & Revenue System
㉟ Journal Entry Carrying Expenses to General Books
㊱ Condensed Sum. of all Expenses to Executives
㊲ Comparative Statement Maint Expense per Equated Track Mile
㊳ Comparative Statement Unit Cost of Main Items of Maintenance
㊴ Statement of Extraordinary Maint Expenses
㊵ Employes and Man Hours Classified
(41) Progress Report on MofW Program

PROCEEDINGS REFERENCES

Block	Exhibit	Volume	Page
1	1 to 4	26	843 to 858
2	'A'	30	646 to 650
3	1 & 2	31	896 to 899
4	1 & 2	31	896 to 899
5	1	34	235 to 237
6	1	34	235 to 237
7	2	27	276 to 284
8	3 & 4	27	276 to 284
9	1	35	614 & 615
10	1	35	614 & 615
11	None	39	676
18	2	37	615 & 617
19	1	40	449 & 450
21	None	39	676
22	None	39	676
27	1	38	553
28	2	38	553
29	3	38	553
34	3	37	620
37	'A	26	776 to 782
38	'B	26	776 to 782
40	4	37	615 to 619

NORTH AND SOUTH RAILROAD
CHART OF
ACCOUNTING AND STATISTICAL REPORT PROCEDURE
IN
MAINTENANCE OF WAY DEPARTMENT

NOTES

Blocks in Broken Lines cover operations incidental to a complete reporting system not touched upon by Committee 11.

Blocks in Full Lines cover forms designed and submitted by Committee 11.

Exhibit 1

name of railroad

I.C.C. ACCOUNT 6 - BRIDGES

Bridge No. Location County State

Val. or Construction Sta. Division Val. Sec.

Name of Contractor Date of Contract

Work Begun Work Completed In Service

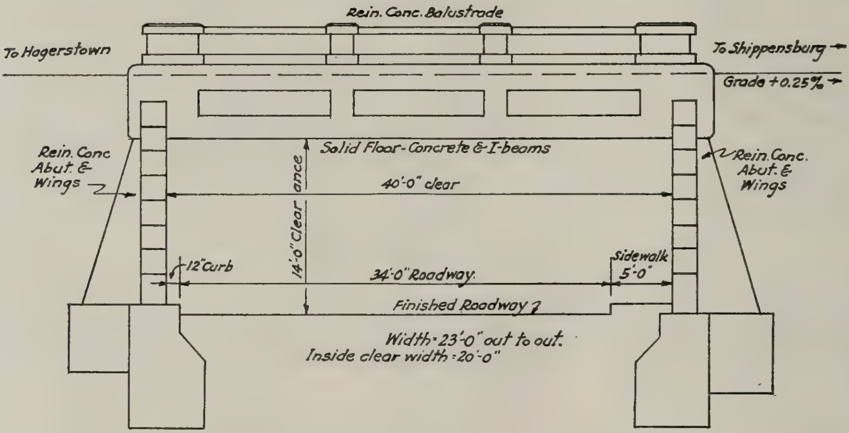
Steel Fabricated by At

Masonry Plans Steel Plans

Loading Rating Steel Specifications

Floor-Solid or Open Alignment Grade No. Tracks

DESCRIPTIVE SKETCH:



Stone ballast - 15" depth Straight

If Federal Aid Project, state following information:

United States Works Program Grade Crossing Project No.

Agreement between Railroad and State dated

Copy of Agreement or Abstract of same attached

Maintenance

Paid for by Ownership

Total Recorded Cost

Exhibit 2

____
name of railroad

OVERHEAD HIGHWAY BRIDGE

Bridge No.__________ Location____________ County__________ State______

Val. or Construction Sta.__________ Division_____________ Val. Sec.__________

Name of Contractor____________________________ Date of Contract___________

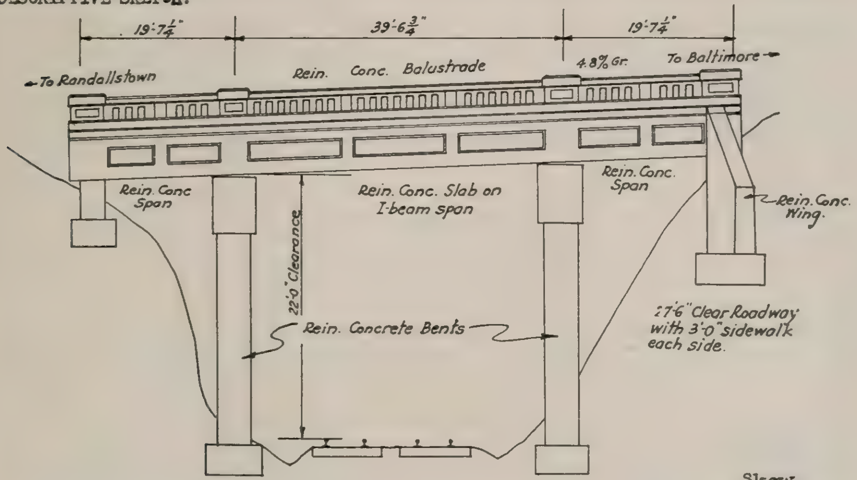
Work Begun______________ Work Completed_____________ In Service___________

Steel Fabricated by________________________ At___________________________

Masonry Plans__________________________ Steel Plans__________________________

Loading - Bureau Public Roads H-__________ Specifications__________________

DESCRIPTIVE SKETCH:



Skew

If Federal Aid Project, state following information:

United States Works Program Grade Crossing Project No. ____________________

Agreement between Railroad and State dated ____________________________

Copy of Agreement or Abstract of same attached____________________________

Maintenance____

Paid for by ______________________ Ownership____________________________

Total Recorded Cost____

Exhibit 3

____
name of railroad

FINAL QUANTITIES
(from Final Estimate Unless otherwise specified)

Location__________ County__________ State__________ Val. Sta.__________ Division__________ Val. Sec.__________ Kind of Bridge__________ Bridge No.______

Foundation Excavation (cu. yds)	Dry	Wet	Depth	Piling, number	______	kind ______	Ave. length below cut-off ______	Total Lin. Ft. ______
Common	______	______	______	" "	______	Treated	do. ______	do. ______
Loose Rock	______	______	______	" "	______	Concrete	" ______	" ______
Solid Rock	______	______	______	" "	______	Steel	" ______	" ______

Foundation Timber - Kind and description with M. B. M.______________________________

Coffer Dams - complete description and quantities______________________________

____

Concrete, Plain,	In substructure	______ cu.yds	In Superstructure	______ cu.yds	Fabricated Structural Steel in place,	I-Beams	______ lbs.
Reinforced,	do.	______ "	do.	______ "	do.	Deck Plate Girders	______ "
______	"	______ "	"	______ "	"	Through Plate Girders	______ "
Concrete Floor Slab			"	______ "	"	Viaducts	______ "
Stone Masonry, kind	"	______ "	"	______ "	"	Trusses	______ "
Brick Masonry	"	______ "	"	______ "	Rip Rap ______ cu.yds.		

Reinforcing Steel in place, Plain Bars ______ lbs. Reinforcing Steel, other than plain, give description:______________ ______ lbs.

Other Steel (alloy, wrought iron, copper bearing, etc.) description______________________ weight ______ "

Waterproofing, type and area waterproofed:______________ Protective coat for concrete work, descrip. & units______________

Backfill, kind______________ quantity ______ cu.yds. Expansion Joints, kind, description & units______________

Roadway paving or surfacing: Kind__________ Sq.Yds______ Sidewalk paving, kind__________ Sq.Yds.______ Curbing, Kind______ Lin.Ft.______

Railing, description______________ Lin.Ft.______ Lighting, description & units______________

Drainage, descr. & units______________________ Wire mesh or cloth, descr. & units______________

Other Items:______________________________

____

____

____

Work performed by Railroad Company______________________________

____

____

Exhibit 4

BRIDGE RECORD

NUMBERING OF BRIDGES

The method of numbering bridges varies on individual railroads, but the majority of carriers use the decimal system, with prefix letters designating branch lines or large divisions, and the prefix "X" for overhead bridges.

It is recommended that the mile and decimal system be used, with prefix letters for branch lines and the prefix "X" for overhead structures, numbering all bridges, culverts and trestles, whether over or under the track. Under the decimal system the number is expressed to the nearest tenth of a mile, except that where two or more structures are located within the same tenth of a mile, it is recommended that all such structures be numbered to the nearest hundredth of a mile.

Some carriers find it more practicable to eliminate the decimal; for example, a bridge located at mile 103.4 would be numbered 1034.

3. Building Records

The committee has carefully reviewed former committee reports dealing with methods of numbering buildings as printed in Vol. 37, pages 623–625 and Vol. 39, pages 683–689, and Register of Buildings as shown in Vol. 39, page 685, Exhibit 7. The information on numbering buildings contained in the Proceedings has been revised and it is recommended that the data shown below be included in the Manual, the first page to be numbered 11–30.2.

BUILDING RECORDS

NUMBERING OF BUILDINGS

A. Preface

Proper identification of buildings is necessary to serve purposes such as the following—record of investment, valuation record, insurance record, tax schedule and maintenance record.

The larger buildings such as stations and enginehouses are easily identified by name, but in large towns and terminals there are usually a number of minor structures having no marked characteristics either as to form or use, and which are frequently moved, altered, or their use changed, making identification difficult. This difficulty may be overcome by a system of numbering all buildings for general and division use.

The methods of numbering, namely the use of metallic plates, stenciling, stamping with steel dies, as well as the systems of numbering to meet conditions on the various roads, are described herein, but no recommendations as to methods or systems are made, as this is a matter for each road to decide.

B. Type of Numbering System

The type of system to be adopted depends on:

(1) Purpose for which used—
    Record of investment.
    Valuation record.
    Insurance record.
    Tax schedule.
    Maintenance record.

(2) Location and character of lines—
One long main line with few buildings.
A network of branch lines in congested territory with many buildings.
A terminal company having no long main line.
A combination of two or more of the foregoing.

Any system adopted should have a permanent scheme of numbering, and should not be dependent on operating divisions, which are subject to change.

C. Definition of Word "Building"

For the purpose of this article, the word "buildings" is deemed to include any structure coming within the various building accounts of the I.C.C. Classification of Investment Accounts and to cover:

Passenger and freight stations.
Office buildings.
Covered sheds.
Derricks and cranes.
Coal trestles, ash pits and sand towers.
Track or wagon scales.
Water tanks, stand pipes, and penstocks.
Signal towers.
Turntables and transfer tables.
Watch boxes.
Drawbridge houses.
Car bodies off trucks.
Dwellings.
Shops and enginehouses.
Power houses and substations.
Coaling stations.

Small items may be omitted from the numbering scheme, such as:

Hose houses and boxes.
Signal boxes and relays, batteries.
Telephone boxes on posts.
Small coal boxes.
Temporary construction buildings.
Toilets and sheds.
Platforms.

Small outbuildings which are a part of a section house, depot, or other building layout, should be included in the field description of the building to which they are accessory, and will not require individual numbers.

D. Buildings Classified as Non-Carrier or Real Estate Buildings Under Lease to Others

These are often located at some distance from the right-of-way, possibly on city streets or other locations where a numbering system might be difficult to apply, in which case it may be desirable to cover such structures by a separate series of numbers, or to use a letter prefix to the number, and possibly to further add in small letters the initials of the owning company.

E. Buildings on Railway Property Owned by Outside Parties

These buildings whether important or not, are or should be a matter of record in connection with the lease of the land on which they stand. A schedule of leaseholds similar to the building schedule, but specifying and describing the occupancy, may be found to be desirable to some carriers, but where this is the case the identification marking should be a separate and distinct system from that used for railroad owned buildings.

Buildings owned jointly by two or more roads should be identified by each owning carrier as if they were solely owned, with the information as to ownership noted on the building schedule.

F. Suggested Systems of Numbering to Meet Various Conditions

(a) *Consecutive Number Only.*—On a road having comparatively few structures, the simplest system is to assign consecutive numbers to each structure from one end of the line to the other. This is not entirely satisfactory as it is not flexible, making no provision for new structures except to add them to the end of the list. Moreover, since a building number should always apply to the structure to which it was originally assigned, regardless of its location at some later date, and should be permanently discarded when the structure is retired, consecutive numbers may eventually have no geographic significance.

(b) *Combination of Letters and Figures.*—Under this system a letter is assigned to each main line or branch of the road, a number to each station, and a separate number to each building at the station.

(c) *Mileage System.*—This consists of numbering each building with the nearest mile from the end of line, using decimals to indicate the exact location. The system is satisfactory for a road consisting of one long main line and few branches, and where the buildings are generally scattered. It is not entirely satisfactory, however, in extensive shops and yards, where numerous buildings would come on the same decimal of a mile, unless supplemented by letters or subnumber designation.

There are several minor variations of the mileage system, such as:

(1) Using decimal of the mile for different structures.
(2) Using consecutive numbers for individual buildings in each mile section.

(d) *Valuation Section and Consecutive Numbers.*—Use the main valuation section number and assign consecutive numbers to each structure in the section.

(e) *Station Name or Number and Consecutive Numbers.*—Assign an arbitrary number to each station group or large yard group, then assign consecutive numbers to each of the structures, starting from one end of the yard. On branch lines where there are few buildings, one station number might be extended to cover a whole branch. While the number in this system does not give any idea as to location, it is believed to be a good system for a railway built up of many short lines with frequent junctions and yards.

(f) *Valuation Sections and Decimal Numbers.*—On most roads the valuation section number denotes ownership; however, where this is not the case it might be desirable to have the ownership marked on the buildings.

Use the valuation section number as the first part or numerator of a fraction and the building number as the denominator. The building number may be assigned as in any one of the various systems outlined above.

G. Methods of Numbering

Types and kinds of numbers are:

(1) Figures put on with paint and stencil. This method, while cheap as to first cost, is not durable and numbers may be lost in repainting.

(2) Enamel or other type of metal plates. This is a rather expensive method, and plates are easily removed, damaged by outsiders or lost by corrosion.

(3) Stamped into the structure with steel dies. This method is cheap as to first cost and the numbers cannot be obliterated without considerable trouble, and if stamped into some portion which is seldom renewed should last as long as the building. It is suggested the number be stamped over the main doorway, or, if this is not feasible, in the wood frame of door at a uniform height of about 5 feet, or in the corner board on track side.

H. Size of Figures

It is suggested that figures be not less than 1 inch high for metal plates and not less than 2 inches high for painted figures.

I. Application of the Numbers

After adopting the system of numbering desired, a schedule should be prepared and the proper numbers assigned, after which they should be applied to the structure.

Every structure on the building schedule should be assigned a number, even though it may not be considered feasible, or necessary, to actually apply the number.

J. Keeping the System Up-to-Date

One office only should have custody of the original schedule, and that office should keep it up-to-date by the assignment of numbers to each new building, as soon as authorized, and the number applied as soon as the building is completed. When a building is destroyed or torn down, the record should be corrected immediately.

When a building is moved from one location to another, the record should be corrected, and if moved into another section the original number should be retained, although it may be supplemented by a subnumber where a system is used in which the number indicates location. In this way the accounting for any one building will always be identified with the number originally assigned to that building.

K. Conclusion

A numbering system should prove valuable to any carrier, but it is recommended that each railroad make a study of its particular problem and select a system best suited to its conditions, and to meet the required purpose.

Register of Buildings

With this report, there is also submitted a form which is recommended for use as a Register of Buildings and which should be prepared by each carrier at the time the buildings are numbered. This schedule should list buildings in the order in which they are numbered and should contain basic data only, such as, building number, location, name or use and date of erection. The form recommended by the committee appears as Exhibit 7 on page 685 of Vol. 39 of the Proceedings, and should be included in the Manual. It is recommended that it be so published on a page immediately following the description of Numbering of Buildings.

Appendix F

(6) Valuation

S. H. Barnhart (chairman, subcommittee), F. B. Baldwin, H. D. Barnes, B. A. Bertenshaw, W. C. Bolin, V. H. Doyle, D. E. Field, C. C. Haire, H. N. Halper, R. J. Herring, A. T. Hopkins, W. R. Kettenring, E. M. Killough, C. A. Knowles, P. R. Leete, Henry Lehn, D. O. Lyle, W. S. MacCulloch, W. S. McFetridge, E. W. Metcalf, H. L. Restall, James Stephenson, H. J. Stroebel, H. C. Wertenberger, Louis Wolf.

(a) Resumé of Developments of the Current Year in Connection With Regulatory Bodies and the Courts

The Interstate Commerce Commission appropriation for the fiscal year beginning July 1, 1939, includes $640,000 for its Bureau of Valuation, the same amount as the previous year. On July 1, 1939, the total force of the Bureau of Valuation numbered 188 employees.

In an endeavor to reduce valuation expenditures, steps were taken to work out simplified practices in valuation recording and reporting and a committee of valuation representatives of the carriers and of the commission conferred during the year to consider these processes.

During the year 1938 Class I carriers charged to Account 459, Valuation Expenses, an amount of $623,463 contrasted with $796,944 for the year 1937.

Carriers have been engaged in filing with the Bureau of Valuation reports required by Valuation Order No. 3, consisting of returns on B.V.Form 588 which contain the details of property changes necessary to bring previous engineering inventories forward to new valuation dates. These returns are likewise utilized by the Land and Accounting sections to revise their land reports and estimates of original cost, respectively. As of October 1, all Class I carriers had filed these returns through the year 1934; 99 percent through the year 1935; 86 percent through the year 1936; 56 percent through the year 1937; and 25 percent through 1938.

The Engineering section of the Bureau of Valuation having completed revised inventories for all Class I carriers through 1927, is engaged in bringing these inventories forward to later dates and as of October 1 had completed 58 percent of the mileage through 1932; 34 percent through 1934; 10 percent through 1936; and 1 percent through 1938. The work of the Accounting section in preparing summaries of original cost and that of the Land section in revising land valuations has advanced to about the same extent.

During the year the Bureau of Valuation spent some time in the valuation of pipe line properties and prepared and served a number of tentative valuations, heard issues raised in protests, and issued final reports on these carriers, all prepared as of December 31, 1934, which was the inventory date. The bureau also spent considerable time in working up estimates for use in a number of rate cases involving switching rates and also in the Barge Line case, involving line haul rates, likewise, in a number of cases involving competitive truck and rail rates. No tentative valuations as of current dates were completed and served on railroad companies, but at the request of the commission, the bureau brought to date the underlying valuation estimates of carriers involved in reorganization proceedings. In some instances reports were prepared showing a property breakdown by mortgages. In a number of cases carriers checked these estimates of original cost, cost of reproduction new—less depreciation, and land values. The Bureau of Valuation also prepared estimates for a number of individual roads relating to the amount of deferred maintenance, if any, for use in one of the rate cases.

Various joint cost data committees composed of the commission's valuation engineers and railroad representatives continued their study of the more important items entering into railroad construction in an endeavor to keep informed as to the current trends, and their reports and conclusions were circularized among the carriers. The 1938 edition of "Railroad Construction Indices" was prepared and released by the Bureau of Valuation. Copies of these reports may be obtained from Mr. E. H. Bunnell, vice-president, Finance, Accounting, Taxation and Valuation department, Association of American Railroads.

Court Decisions

During the year efforts were continued to shorten the valuation processes in public utility cases which some regulatory bodies believed responsible for the delay in the final disposition of cases coming before them. In one case which reached the Supreme Court a brief was filed as *amicus curiae* to which were attached the names of counsel of the Department of Justice, the Federal Power Commission, the Federal Communications Commission and the Securities and Exchange Commission. It was urged that a procedure be adopted whereby prudent investment would be substituted for the long established rule that the cost of reproduction must be determined and considered in the establishment of a rate base. The attempt to secure the adoption of such a rule again proved unsuccessful. It is noteworthy that the name of the Interstate Commerce Commission was not affixed to this brief and the commission in its valuation of railroad properties continues to report all of the elements of value it has heretofore been considering in arriving at a single sum value reported by it under the Valuation Act.

During the year a number of cases involving valuation were decided by Federal and State Courts, of which the following is a resume:—

In the U. S. Supreme Court in the case of Driscoll, et al, v. Edison Light and Power Company decided April 17, the court again refused to depart from the rule adopted more than 40 years ago in the Smyth v. Ames case which marked the beginning of the famous "fair value" rule and a long line of decisions upholding that method. In the Pacific Gas and Electric Case commented upon in last year's report, and again in this report, attempts were made to make prudent investment the sole rate base factor in utility cases to the exclusion of reproduction cost, on the theory that the delays incurred in making an up-to-date appraisal obstructed the rendering of prompt decisions by utility commissions. The Driscoll case grew out of enactment by the Pennsylvania legislature of a law similar to that enacted in New York providing for temporary rates sufficient to yield not less than 5 percent on original cost less accrued depreciation, such rates to be effective pending determination of permanent rates and providing a recoupment in the latter of any deficit caused by the former. When the case reached the courts the lower court held the law unconstitutional because it permitted the commission to fix temporary rates based on the single factor of original cost less accrued depreciation. The Supreme Court in an opinion delivered by Justice Reed did not decide that issue, holding that it looked at the question on an interpretation of the Pennsylvania statute by the board charged with its enforcement that it must weigh all essential elements of value required by past decisions. It pointed out, however, that the commission had not only given weight to reproduction cost, original cost, working capital, but also to going value even to the extent of finding a value several hundred thousand dollars in excess of its average of reproduction and original costs, both depreciated. Having found that the commission had proceeded as required by past decisions and that the rates ordered were sufficient to yield even more than 5 percent, the Supreme Court lifted the injunction granted in the lower court. Justices Frankfurter and Black filed an interesting concurring opinion, stating among other things, "The Court's opinion in the present case does not avoid the issue of constitutionality. It accepts the much more dubious constitutional doctrines of Smyth v. Ames and its successors to solve the very easy constitutional issue raised by the Pennsylvania Act."

The Wisconsin Supreme Court on July 11 decided a case involving both valuation and depreciation. The case was that of the Wisconsin Telephone Company v. Public Service Commission of Wisconsin. It arose from the attempt of the Wisconsin commission to reduce telephone exchange rates in the state. Two separate opinions were filed in the case. In speaking of valuation the opinion of the court states that "while we adhere to the rule laid down by the Supreme Court of the United States, it is difficult to see why a valuation arrived at by guess on the basis of estimates should form the legal base for depriving a litigant of its property, or the justification of excessive charges to the public." The opinion of the court expresses some of its views with reference to valuation of public utility properties, stating:

> At this point we digress for the purpose of expressing some views with reference to valuation of public utility properties. While the commission said that it gave and there is no reason to suppose that it did not give consideration to book investment, the whole emphasis throughout this valuation proceeding covering a period of nearly five years has been placed upon the cost of reproduction new. When Smyth v. Ames, supra, was decided, public utilities were subject to little if any effective regulation. In the financial structure of utility companies, especially railway companies, was to be found a large amount of so-called water. There was no systematized accounting and it was practically impossible to discover from the records of a utility company the so-called book cost of the property. There was therefore no other practical way to ascertain its value than to consider what it would cost to reproduce it new and then depreciate that cost to the present condition of the plant being valued. Here we have a plant which has been under state supervision since 1911 and under federal supervision since 1913, has been required annually or oftener to report to regulating authorities every dollar of its earnings and expenditures and at all times it has been subject to strict supervision as well as regulation. Just why a million and a half to two million dollars should be spent in appraising a hypothetical plant that would never be rebuilt, under assumed conditions that never can exist, on the basis of price levels which are mere estimates, by a construction force which must be hypothetical and then assume that that represents the fair value of the plant and give it controlling weight as against the book costs which are disclosed by records kept under strict governmental supervision, is difficult to see. We expressed dissatisfaction with the emphasis placed upon reproduction new in valuing the property of public utilities in Waukesha Gas & E. Co. v. Railroad Comm. (1923), 181 Wis. 281, 194 N. W. 846. There is considerable evidence that it will ultimately cease to be a dominant factor in utility valuation practice in cases where other more accurate and realistic bases are available.

Nevertheless the court found and used as the rate base reproduction cost new less observed depreciation of 9.79 percent, and finding that the old rates yielded but 5 percent thereon, concluded that the old rates were not unreasonable and therefore affirmed the restraining order issued by the lower court. The court held that depreciation should be measured by neither inspection nor straight line formulas, but by service capacity which, in the case placed before the court, was 90 percent as against the commission's 71.53 percent condition. The company's engineer had found by inspection 9.79 percent depreciation; the commission's engineer by office calculations, 28.47 percent. In speaking of the adoption by the commission of a theoretical basis of maintenance expenses, the court found that the amount which shall be expended by a public utility in the operation of its plant is in the first instance a question for the management and that the commission is invested with no managerial powers. In the companion case involving depreciation charges the court upheld the commission's order prescribing composite depreciation rate of 3.56 percent as compared with a composite of 4.53 percent proposed by the telephone company. The court stated:

> The question of what constitutes a proper depreciation charge when applied to the property of a public utility is one of the most controversial and elusive with which courts are called upon to deal. Engineers and accountants disagree violently not only upon principles to be applied but upon the method of their application. In this case, the depreciation rates prescribed by the commission applied to the book value of the depreciable property as at the end of 1934 composite to 3.56 percent as compared to a composite of 4.53 percent proposed by the company. The difference between the rates ordered by the commission and those proposed by the company approximate $700,000 in annual depreciation expense for the entire property. It is not to be denied that the amount of the depreciation charge is a matter of vital importance to the company. The Supreme Court of the United States has said that if the company fails to make a sufficient depreciation charge and by reason of that fact is ultimately deprived of some of its property, it is its own fault. On the other hand, if the depreciation charge is too high, subscribers are compelled to make capital contributions to the company. * * *
>
> It is apparent from the fact that the company has maintained its plant over the years in a condition 90 percent efficient and had accumulated a large depreciation reserve that a reduction in the annual depreciation allowance must be made if the rate payers are not to continue to make capital contributions to the company. What the amount of the depreciation charge should be is largely a prediction. We have given this matter careful consideration, and it is considered that this Court cannot say upon the record that the depreciation rates established by the commission are unreasonably low. While it is quite apparent that they are not generous, and probably leave a very small margin, they cannot be set aside for that reason. It appears to us that this matter of the amount of depreciation charge is one peculiarly within the province of the commisssion and not to be disturbed by the Court except in a clear case. The effect of the depreciation charge must be considered in connection with the maintenance account. It is not the function of the commission either in establishing the depreciation charge or fixing a rate to pare the charge or the rate down to the lowest possible figure. That, as we have already pointed out, does not meet the test of reasonableness. However, in this case we are not dealing directly with revenue but with only one factor which affects net revenues. * * *

In the case of the City of Jefferson v. Capital City Water Company decided December 21, 1938, by the Public Service Commission of Missouri, the commission rejected the theory that the depreciation reserves should be deducted from the estimates of original cost, stating:

> We will accord due consideration to accrued depreciation in arriving at our conclusions of the present fair value of the property but will make no deductions on that account in the process of arriving at an estimate and conclusion on the subject of original cost.

(b) Study of Valuation Order 3 Reports and Records to Determine if Further Simplifications Are Possible

Developments in connection with simplification of Valuation Order 3—Reports and Records—are set forth in a communication dated March 20, 1939, addressed—"To Officers in charge of Valuation Order No. 3—Records and Reports", by E. H. Bunnell, vice-president, Finance, Accounting, Taxation, and Valuation Department of the Association of American Railroads.

The majority of the members of the special committee which handled these matters of simplification of Order 3 returns with the Bureau of Valuation, I.C.C. are also members of Subcommittee 6, Committee 11 AREA. This communication of March 20, 1939, follows:

March 20, 1939.

To Officers in Charge of Valuation Order No. 3 Records and Reports:

At the time revised Supplements 4 and 5 to Valuation Order No. 3 were issued, a Circular Communication to Executives and Chairmen of Valuation Committees, No. 1597-Ex.-Ch., dated October 18, 1933, was issued by Mr. Hulme, vice-chairman, Presidents' Conference committee, in which a general platform of co-operation with the Bureau of Valuation and agreement on simplification of Valuation Order No. 3 records and reports by individual carriers was recommended. In furtherance of this recommendation, certain modifications and reductions were authorized by the Bureau of Valuation on application of individual carriers.

As a result of a review by Subcommittee E-1, Valuation, of Committee 11, Records and Accounts, of the American Railway Engineering Association and the valuation staff of this department, certain suggestions as to simplification of Valuation Order No. 3 records and reports were recommended, which, after proper application by individual carriers to the Bureau of Valuation, would be authorized. These were sent to chairmen of valuation committees with my circulars of December 10, 1935 and December 29, 1936.

The subject of further simplification of Valuation Order No. 3 records and reports was assigned by me to a committee consisting of Messrs. J. H. Roach (chairman), F. B. Baldwin, S. H. Barnhart, C. A. Knowles, and D. O. Lyle. This committee made a preliminary report dated October 20, 1938, copy of which was sent you, including suggestions received from carriers up to that time. This report contains two parts—Schedule (A) entitled "Those Modifications and Reductions Which Have Been Authorized From Time to Time Over Past Years" and Schedule (B) entitled "New Items of Simplification Brought up for Discussion."

Subsequently all of the carriers were canvassed by me for suggested modifications and simplifications, all of which were presented by the committee in conferences with the heads of the Engineering and Accounting sections of the Bureau of Valuation on January 4–5, 1939, followed by brief discussions on January 6, 7 and 10, including discussion with the Land section of the bureau on the latter date.

As a result of these discussions it was clear to the committee that the bureau representatives are definitely opposed to any revision of Valuation Order No. 3 and Supplements 4 and 5, insofar as questions presented by the committee at this time are concerned. For your information and guidance there is attached revised Schedule (A), incorporating those modifications and reductions which have been authorized by the bureau from time to time over the past years on application of individual carriers and, resulting from the recent conferences, revised Schedule (B), incorporating additional modifications and reductions which the bureau now authorizes as permissible, based on their interpretation of the existing orders.

The extent to which an individual carrier's records and reports may be further simplified to suit their individual needs is a matter for conference between the individual carriers and the Bureau of Valuation.

E. H. Bunnell.

Revised Schedule (A)

Those Modifications and Reductions Which Have Been Authorized From Time to Time Over the Past Years Upon Application of Individual Carriers

1. Some carriers continue to show unit costs in their completion reports for various installations other than by contract unit prices, which is not required by the orders. The elimination of such unit price analysis results in considerable reduction in work and expense in cases where it is not required for carrier purposes.
2. Account 2, Land. On large projects where a large number of land parcels are involved, it is suggested that the land information be placed directly on the L and M forms for attachment to the 588 returns, using copies of the same L and M forms also as a subschedule to be attached to the completion report, resulting in eliminating duplication of the data in the completion reports and the L and M forms.

3. Where items in Acct. 37, Roadway Machines, have all been transferred to the operating company and are common to all valuation sections, a substantial reduction in the volume of 588 returns results from a consolidated report, reporting as unallocated, if satisfactory.
4. Report the average cost of each group or series of freight-train cars and other equipment, instead of the cost of individual units.
5. Equipment records may be maintained to serve as a combined Equipment Completion Report and Record of Property Changes and also as a Subschedule to B.V. Form 588. Such combined record may be substituted for Forms Exhibits D and E.
6. In cases where complete structures are retired attention is called to the fact that Supplement 5 provides: "The retirement of a complete structure individualized in the basic reports need be described only to the extent necessary to permit ready identification of such structure in the basic reports." This will include installations reported on Form 588.
7. Eliminate duplicate sources of field information in the carriers' records from which the completion reports are prepared.
8. Notes on loss and waste. Show this once only for Accounts 10 and 11 on the first sheet of the 588 return.
9. Carbon-backed copies of Form 588 returns may be eliminated.
10. A blank sheet for each account showing "Nothing to Report" may be discontinued. This fact will be sufficiently indicated in the first sheet of the 588 return for each valuation section by the absence from the list of accounts included in the return to which debits and credits were made.
11. Reduction in number of valuation sections. Par. 26 of Revised Supplement 5 provides "Appropriate combinations of present valuation sections should be made within practical limitation, to promote facility and economy, subject to the approval of the Bureau of Valuation."

Revised Schedule (B)

New Items of Simplification Authorized by the Bureau of Valuation

1. The following applies in all accounts for reports on Form 588:

> "Inconsequential items, when occurring infrequently, or miscellaneous items appurtenant to a larger installation, aggregating $500 or less, may be reported as a 'lot' with a brief description and cost, in line with the handling of minor items in Acct. 44 as provided in revised Supplement No. 4."

The above method may be used in the completion reports where carriers have available the consist of the "lot" total.

2. In reporting changes in an existing structure not seriously affecting the reproduction cost, such as the removal or re-arrangement of partitions, placing additional doors and windows, etc., or other changes within a building, when the size or type of structure is not changed, it is necessary to furnish only an essential description of the change and its cost.
3. It is permissible to eliminate equipment Sub-schedule (b) and place information on Form 588 in condensed form for each equipment group.
4. For structural property the Record of Property Changes need be simply an index listing the A.F.E., completion report number and showing the cost, without recording thereon the units, quantities and descriptions, since the completion report will serve as a sub-schedule to the Record of Property Changes.
5. The grand summaries showing the classification of property by ownership, states, etc., are desired by the bureau, in accordance with their letter requests to individual carriers, but separate summaries are not needed for each valuation section.
6. The bureau representatives were unwilling to consider any revision of the commission's order requiring affidavits on completion reports but suggested that each individual carrier confer with them and work out arrangements for their road, if this requirement is burdensome on account of responsibility not being centralized.

7. It is preferable to complete and file the annual Form 588 return rather than hold same for a few delayed Completion Reports in cases where they amount to a minor proportion of the total annual return. Any differences would be covered by the reconciliation statement.

8. It will be permissible to consolidate in the completion reports, the units, quantities and costs for main tracks with yard tracks and sidings for Acct. 8, Ties; Acct. 10, Other Track Material; and Acct. 11, Ballast; in those cases where carriers maintain an individual track record which shows units and quantities in each track, and where this latter information is filed in support of the completion report and is readily accessible to the field examiners.

9. Where the records referred to in Par. 8 foregoing underlie the completion reports and are readily available with the completion reports at the time of the field examiner's check, it will be permissible for carriers to record Acct. 10 items on the cwt. basis in the completion report.

10. The known units, quantities and the costs of inventoriable items in Acct. 2½ and in Acct. 39 (former Acct. 15 items) should be recorded and reported on B. V. Form 588.

11. In cases where property involving old Acct. 15 items is retired and not replaced and the cost is transferred to either Acct. 2½ or Acct. 39, a brief description of each case transferred will be sufficient without showing any units and quantities under Acct. 2½ or Acct. 39 on the Form 588. The retirement of the units and quantities included in the old crossing should be reported in the usual way.

12. The Land section states that it would greatly assist them if carriers would keep the valuation maps posted up to date to reflect land changes reported in the annual 588 returns on Subschedules L and M, in order to have the up-to-date maps available to furnish when requested by the bureau.

13. The Bureau of Valuation calls attention to the lack of co-ordination between carriers in reporting changes and new construction of jointly constructed property, such as interlocker plants, signals, bridges, crossings, etc. This results in substantial inconsistencies in both units and costs shown in B. V. Forms 588 as submitted by the several partcipating carriers for the same property change. Much extra work and correspondence can be eliminated on the part of the bureau, as well as the carriers, if the carrier making the change would make an extra carbon copy of its B. V. 588-R sheet, reporting the jointly constructed property, and then send this copy to each participating carrier for its use. In the event there are any differences or disagreements, such matters should be reconciled before the returns are submitted to the bureau. Several carriers have simplified their work by following this procedure.

(c) Form of Order 3 Reports in Connection With Joint Projects, Federal—Railroad

Your committee has given continued consideration to this subject during the year but has not as yet been able to develop the form or outline of reports due to continuing indecision with respect to the inventory classification of such property.

It is recommended that the subject be continued.

(d) Forms For a Record of Ballast Installations

There have been no further developments during the year in connection with this subject. The opinions or suggestions of the committee, contained in the report for last year (recorded at page 453, volume 40 of the Proceedings), have continued during the present year and the committee is doubtful whether or not forms for a record of ballast installations can be developed which may be advantageous either as a guide or for use by individual carriers. The committee invites attention however to Form No. 1114 of the Manual found at page 11-23. It is recommended that the subject be continued.

Appendix G

(7) Changes in or Revisions of I.C.C. Classification of Accounts

H. D. Barnes (chairman, subcommittee), Anton Anderson, F. B. Baldwin, S. H. Barnhart, B. A. Bertenshaw, W. C. Bolin, W. F. Cummings, V. H. Doyle, D. E. Field, C. C. Haire, H. N. Halper, J. H. Hande, R. J. Herring, W. R. Kettenring, C. A. Knowles, Henry Lehn, W. M. Ludolph, O. M. Miles, A. T. Powell, H. L. Restall, C. P. Richardson, H. C. Wertenberger.

In accordance with the arrangements outlined on page 746 of Volume 40, Proceedings for 1939, this committee has reviewed the following tentative accounting cases or orders submitted by the Bureau of Accounts of the Interstate Commerce Commission and information reflecting the opinions of the members furnished Mr. Bunnell, vice-president of the Association of American Railroads:

I.C.C. Bureau of Accounts Subject No.	*Subject*
186	Proposed revision of the following "A" cases: A–4. Accounting for amounts received from pipe line companies and others for rights to construct and maintain pipe lines on a carrier's right-of-way. A–6. Accounting for exchange of land, both when there is and when there is not a cash consideration. A–8. Accounting for percentages added to bills to cover transportation, superintendence, use of tools, store expense, etc. A–13. Accounting for rail and other track material leased to others (other than industrial track agreements) and for the construction of an industry track when all or part of the cost is borne by the industry. A–16. Accounting for carrier's liability for an award under the Workmen's Compensation Act. A–21. Accounting by lessee for retirements in connection with improvements on leased railway property. A–30. Accounting for Federal and State taxes assessed on lubricating oils and gasoline, and for state and city sales taxes imposed on materials and supplies. A–56. Accounting for most frequently occurring settlements of claims for loss and damage. A–75. Accounting for loss due to depreciation of rail and other track material returned to stock after having been leased. A–103. Accounting for overhead charges included in bills against others in connection with the construction of industry tracks and railway property for an undergrade highway crossing. A–104. Accounting for profit and loss items included in a terminal company's joint facility bills against tenant companies.
189	Proposed modification in the Road and Equipment, Income, Profit and Loss and General Balance Sheet accounts for steam roads to provide for a revision in accounting for capital and earned surplus.
194	Proposed revision of Case A–26 covering the accounting for preliminary surveys and studies.
197	Proposed modification of the Classification of Investment in Road and Equipment Account 41—Cost of Road Purchased and creation of a new Account 78—Difference between the Price Paid for Property Acquired and the Money Outlay for the Construction and Improvement of that Property.
201	Proposed revision of Case A–94 covering the disposition of balances in Account 15—Crossings and Signs as of December 31, 1935 and accounting for subsequent retirement of property at highway and private crossings.

I.C.C. Bureau of Accounts Subject No.	*Subject*
202	Proposed revision of Case A–109 covering the accounting for the replacement of an overhead highway bridge at the expense of a public authority.
203	Proposed revision of Case A–110 covering accounting in connection with replacement of highway grade crossing with overhead highway bridge.
204	Proposed revision of Case A–111 covering accounting for the replacement of an overhead highway bridge constructed partly or entirely at the carrier's expense with a new structure, the cost of which is borne partly or entirely by the carrier.
205	Proposed cancellation of Case A–115 covering the accounting in connection with highway crossing improvements in progress on January 1, 1936 and for the replacement of highway facilities.
206	Proposed cancellation of Case A–140 which pertained to an apparent conflict between the provisions of Cases A–109 and A–111, and Section 6 of the general instructions of the Classification of Investment in Road and Equipment of Steam Roads.
210	Proposed revision of minimum rule in I.C.C. Classification of Investment in Road and Equipment.
211	Proposed revision of Case A–10 covering the investment in and rental from structures not used by a carrier in transportation service or service incidental thereto.
213	Proposed revision of Case A–24 covering accounting for improvements on leased railway property.
214	Proposed revision of Case A–137 covering the accounting for the installation of highway crossing protection at the joint expense of a carrier and a public authority.
215	Proposed revision of Case A–143 covering the accounting for the replacement of a section of right-of-way fence.
216	Proposed order cancelling R. & E. Account 25—Gas Producing Plants, Operating Expense Account 245—Gas Producing Plants and amending answer in Case 221 Accounting Bulletin No. 15.
217	Proposed ruling in connection with clearing Account 754—Grants in Aid of Construction, when related property is retired from service.
220	Proposed order modifying accounting for grade separation and protection projects and certain other joint projects.
222	Proposed "A" case clarifying accounting Series Circular No. 62, issued April 4, 1928, pertaining to transportation on materials and supplies.
223	Proposed order cancelling Account VIII—Transportation for Investment—Cr. in the Operating Expense Classification, and making other necessary changes in the Classification of Investment in Road and Equipment.
224	Proposed order establishing Account 36—Furniture and Office Equipment.
225	Proposed order providing for the classification of property as between carrier and non-carrier.
226	Proposed ruling with respect to accounting for construction losses.
227	Proposed ruling with respect to accounting for raise of grade.
228	Proposed order modifying instructions pertaining to adjustment for converted property
230	Proposed order modifying text of Account 3—Grading by elimination of "Reconstruction of highways."
232	Proposed order modifying instructions for accounting for ballast.

. The Interstate Commerce Commission has made no changes in the accounting classifications since this committee's last report (pages 453 and 454, Vol. 40, Proceedings for 1939). The Bureau of Accounts has, however, released one additional series of accounting rulings and reissued, under date of September 14, 1939, Cases A–1 to A–149, inclusive, including cancellations and revisions, together with additional "A" cases 150 to 152, inclusive. The committee in this report describes briefly only those new cases and the cancellations or revisions of old cases involving the investment or other accounts used in connection with accounting for construction, maintenance or retirements as follows:

ACCOUNTING CASE SERIES NO. 18 (FEBRUARY 24, 1939)

Case A–144—Accounting for transportation, incidental fuel and supplies furnished by a carrier in connection with installation of highway crossing protection otherwise paid for and owned by a public authority.

Case A–145—Accounting for estimated value of salvage from roadway property retired in advance of the dismantling of such property.

Case A–147—Accounting for the cost of cranes, derricks and automobiles when permanently mounted to move over a carrier's standard track.

Case A–149—Accounting for the retirement of tracks when two carriers co-ordinate the use of their tracks between two points, permitting the abandonment of part of the trackage of each.

REVISIONS AND CANCELLATIONS EFFECTIVE SEPTEMBER 1, 1939

Case A–8—Revised—Accounting for percentages added to bills to cover transportation, superintendence, use of tools, store expense, etc.

Case A–10—Revised—Accounting for the investment in and rental from structures not used by a carrier in transportation service or in service incidental thereto.

Case A–13—Revised—Accounting for rail and other track material leased to others, and for the construction of an industry track when part or all the cost is borne by the industry.

Case A–26—Accounting for the cost of preliminary surveys and studies, and the disposal of such costs when the proposed project is authorized or abandoned.

Case A–30—Accounting for federal and state taxes assessed on lubricating oils and gasoline, and for state and city sales taxes imposed on material and supplies.

Case A–36—Revised—Cancelled. This case specified the accounting for sales taxes.

Case A–92—This case cancelled or revised certain other "A" cases and these changes are reflected in the cases as reissued.

Case A–94—Revised—Modifies the previous ruling with respect to accounting for the retirement of property at highway and private crossing which the Bureau of Accounts has excluded from its classification of property used in transportation service.

Case A–103—Revised—Accounting for overhead charges included in bills against others in connection with the construction of undergrade crossings at the expense of public authorities, or industry tracks at the expense of the industry.

Case A–109—Revised—Accounting in connection with the replacement, at the expense of a public authority, of an overhead highway bridge; when the cost of the original bridge was borne by the carrier, and when it was borne by others.

Case A–110—Revised—Accounting for the replacement of a highway grade crossing with an overhead bridge.

Case A–111—Revised—Accounting for the replacement of an overhead highway bridge constructed partly or entirely at the carrier's expense with a new structure, the cost of which is borne partly or entirely by the carrier.

Case A–115—Cancelled—This case was in connection with the elimination of Account 15—Crossings and Signs from the Classification of Investment in Road and Equipment, effective January 1, 1936.

Case A–137—Revised—Outlines the accounting for the installation of highway crossing protection at the joint expense of the carrier and a public authority when the facilities are owned, maintained and operated by the carrier.

Case A–140—Cancelled—This case pertained to Cases A–109 and A–111, and the revision of those cases necessitated its cancellation.

Case A–143—Cancelled—This case was in connection with the accounting for the replacement of right-of-way fences.

Case A–150—Accounting for units of equipment withdrawn from transportation service and held as an historical specimen or for exposition material, and also the accounting for the reproduction of old units for these purposes.

This report is submitted as information with the recommendation that the subject be continued.

Appendix H

(8) Method of Avoiding Duplication of Reports and for Simplifying and Co-ordinating Work Under the Requirements of the I.C.C. and Other Public Authorities

F. B. Baldwin (chairman, subcommittee), W. C. Bolin, H. D. Barnes, S. H. Barnhart, H. N. Halper, C. A. Knowles, P. R. Leete, D. O. Lyle, W. S. MacCulloch, C. K. Smith, Jas. Stephenson, Louis Wolf.

There has been no further progress growing out of the attempts of the Association of American Railroads to secure the further simplification in the matter of governmental reporting than that reviewed in the report of last year. Recent developments would seem to indicate the need for further activities.

The Committee on Statistics and Accounts of Railroad Companies of the National Association of Railroad and Utilities Commissioners in a statement to President Mahood regarding Mr. Pelley's letter reported at the 1938 convention of that body as follows:

> All or practically all of the reports now required of and filed by carriers are either specifically prescribed by statute or reports which call for specific information needed and necessary in the administration of certain provisions of law; that the requirements for filing said prescribed returns under provisions of the statute have not been extended by regulation, hence the state departments are without legal authority to authorize the discontinuance of any of the reports now being made.

A recent session of Congress appropriated $40,000 additional to the Bureau of Statistics to pursue the subject of cost finding which would provide for an increase of about 11 people in its force. This force is to assist in establishing costs of the various forms of transportation, including rail, truck and pipe lines, and it is probable that the demands of the Bureau of Statistics upon the railroads will be increased rather than decreased.

The committee appointed by E. H. Bunnell, vice-president, Association of American Railroads, under the chairmanship of J. H. Roach, chief valuation engineer, New York Central Lines to simplify Valuation Order No. 3 records and reports completed its assignment and made its report and the results were circularized under date of March 20, 1939. In order that the subject might have continuous consideration, two subcommittees of the Valuation Advisory committee have been appointed, one an engineering committee under the chairmanship of Mr. Roach and the other an accounting committee under the chairmanship of C. A. Knowles, valuation engineer, Chesapeake & Ohio. These committees will continue to give consideration to those simplifications which it is thought by the carriers should be placed in effect to keep the reports and requirements of the Bureau of Valuation at a minimum cost to the carriers and at the same time furnish the bureau essential information.

This report is submitted as information with the recommendation that the subject be continued.

Report of Special Committee on Impact

J. B. HUNLEY, *Chairman,*	A. N. LAIRD	G. E. ROBINSON
O. F. DALSTROM	P. G. LANG, JR.*	C. P. SCHANTZ
S. F. GREAR	B. R. LEFFLER	F. E. TURNEAURE
M. HIRSCHTHAL	J. A. NEWLIN	W. M. WILSON
C. S. JOHNSON		*Committee.*

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* Died December 9, 1939.

To the American Railway Engineering Association:

Your committee reports as follows:

No progress can be reported at this time on any of the subjects assigned to the committee, as no funds have been available for its use during the past year. However, a certain sum has been authorized for its work during 1940, and while this amount is not sufficient to undertake additional tests, it will provide for the employment of some one to analyze existing data, from which it is expected that additional valuable information as to the subject of impact will be obtained.

It is recommended that the following subjects, previously assigned, be continued:

1. Tests of short steel spans with open floor, together with effect of inequalities of track and effect of worn wheels on such track.
2. Tests of steel spans with ballasted deck, including spans with precast and poured-in-place concrete decks; also tests on ballasted decks with timber floor; particular attention to be given to the damping due to the type of deck and the track ballast.
3. Tests of dynamic shear in girder spans and truss spans.
4. Tests of impact in columns and hangers of steel spans.
5. Tests of rigid frame structures of steel and concrete.

THE SPECIAL COMMITTEE ON IMPACT,
J. B. HUNLEY, *Chairman.*

Bulletin 415, January, 1940.

Report of Committee 17—Wood Preservation

C. F. FORD, *Chairman,*
W. G. ATWOOD
DR. S. J. BUCKMAN
WALTER BUEHLER
C. S. BURT
G. B. CAMPBELL
DR. W. F. CLAPP
H. R. CONDON
E. A. CRAFT
H. R. DUNCAN
JOHN FOLEY
E. B. FULKS
W. R. GOODWIN
L. H. HARPER
L. B. HOLT
H. E. HORROCKS
R. S. HUBLEY
R. P. HUGHES
M. F. JAEGER
DR. A. L. KAMMERER
EDWARD KELLY
W. S. KING*
A. M. KNOWLES
A. J. LOOM
R. S. BELCHER,
Vice-Chairman,
F. D. MATTOS
L. J. REISER
F. B. ROBINS
DR. HENRY SCHMITZ
L. B. SHIPLEY
O. C. STEINMAYER
G. C. STEPHENSON
T. H. STRATE
W. A. SUMMERHAYS
DR. HERMANN VON SCHRENK
Committee.

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* Died April 14, 1939.

To the American Railway Engineering Association:

Your committee respectfully reports on the following subjects:

1. Revision of Manual. Progress in study—no report.

2. Service test records for treated ties (Appendix A). Progress report.

3. Piling used for marine construction (Appendix B). Progress report.

4. Effect of preservative treatment by use of

   (a) creosote and petroleum.
   (b) zinc chloride and petroleum.

Progress in study—no report.

5. Destruction by termites and possible ways of prevention (Appendix C). Progress report.

6. Revision of specifications for the treatment of Douglas fir. Progress in study—no report.

7. Incising of all forest products material. Progress in study—no report.

8. Investigations being made for the determination of toxicity value of creosote and creosote mixtures. Progress in study—no report.

9. Present practice as to preservatives used (Appendix D). Progress report.

THE COMMITTEE ON WOOD PRESERVATION,
C. F. FORD, *Chairman.*

Bulletin 416, February, 1940.

Appendix A

(2) Service Test Records for Treated Ties

A. J. Loom (chairman, subcommittee), G. B. Campbell, W. R. Goodwin, L. H. Harper, L. B. Holt, R. S. Hubley, R. P. Hughes, M. F. Jaeger, Edward Kelly, T. H. Strate, W. A. Summerhays.

The table of tie renewals per mile maintained on various roads has been revised to include data for 1938.

Reports of special test tracks are submitted for the following roads:

Atchison, Topeka and Santa Fe
Canadian National Railways
Canadian Pacific Railway
Chicago, Burlington and Quincy
Chicago and Eastern Illinois
Chicago, Indianapolis & Louisville
Great Northern
Northern Pacific
Union Pacific

(Inspection reports are submitted by the Forest Products Laboratory covering the installation in the test track near Fair Grounds, Madison, Wis., and the Hartford, Wis., test section of the Chicago, Milwaukee, St. Paul & Pacific, also the Laramie test track of the Union Pacific.)

The above is offered as a progress report.

CONDITIO

Zinc chlori
Zinc chlori

Mercuric c
Mercuric c

Creosote...
Creosote...
Creosote...
Creosote...
20% creoso
20% creoso
Semi-refine
Semi-refine
Zinc chloric
Zinc chloric
Zinc chloric
Zinc chloric
Untreated[3].
Untreated[4].

CROSS TIE RENEWALS PER MILE OF ALL TRACK MAINTAINED 1911-1940

COMMITTEE 7 – A.W.R.A.

YEAR	AT&SF	B&O	CB&Q	C&E	CCC&StL	CMStP&P	CRI&P	DL&W	GT NORTHERN	ILLS CENTRAL	KC SOU	LEHIGH VALLEY	MICH CENT	MK&T	MONON CI&L	NYC (EAST)	NYC (WEST)	NOR PACIFIC	PENNA	SOO LINE	SOUTHERN PAC (ATLANTIC SYST)	SOUTHERN PAC (PACIFIC SYST)	UNION PACIFIC	C R R of N J	READING	BOSTON & MAINE	C & O	NEW YORK CENTRAL			TOTALS FOR ALL ROADS MILES	NO. OF ROADS	TIES PER MILE	5 YR AVG
1911	[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]					[illegible]	[illegible]	[illegible]	[illegible]
1912	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]					[illegible]	[illegible]	[illegible]	[illegible]
1913	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]					[illegible]	[illegible]	[illegible]	[illegible]
1914	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]					[illegible]	[illegible]	[illegible]	[illegible]
1915	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]					[illegible]	[illegible]	[illegible]	[illegible]
1916	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	[illegible]	[illegible]
1917	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	[illegible]	[illegible]
1918	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	[illegible]	[illegible]
1919	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	[illegible]	[illegible]
1920	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	[illegible]	[illegible]
1921	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	[illegible]	[illegible]
1922	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	[illegible]	[illegible]
1923	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	[illegible]	[illegible]
1924	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	[illegible]	[illegible]
1925	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	[illegible]	[illegible]
1926	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	[illegible]	[illegible]
1927	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	[illegible]	[illegible]
1928	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	[illegible]	[illegible]
1929	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	[illegible]	[illegible]
1930	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	[illegible]	[illegible]
1931	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	[illegible]	[illegible]
1932	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	[illegible]	[illegible]
1933	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	[illegible]	[illegible]
1934	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	[illegible]	[illegible]
1935	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	[illegible]	[illegible]
1936	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	27	[illegible]	[illegible]
1937	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	27	[illegible]	[illegible]
1938	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	27	104	104
1939																																		
1940																																		

⊗ Main Line Only ① Included [illegible]

CONDITION OF EXPERIMENTAL TIES IN THE CHICAGO, MILWAUKEE, ST. PAUL & PACIFIC TEST TRACK NEAR HARTFORD, WIS., AFTER ABOUT 28 YEARS SERVICE

Ties Set October, 1911

Preservative	Process	Tie plates	Average absorption lb. per cu. ft.	Ties in test	Condition of ties—October, 1939					
					Serviceable		Removed			
							Mainly for decay		Mainly for causes other than decay[a] and unknown causes[b]	
				No.	Number	Per cent	Number	Per cent	Number	Per cent
			Chestnut							
Zinc chloride[1]	Burnett[c]	Flat	12.5[d]	10	---	---	5	50.0	5	50.0
Zinc chloride[2]	Burnett[c]	Ribbed	12.5[d]	13	---	---	6	46.1	7	53.9
			Spruce							
Mercuric chloride	Kyan	Flat	---[e]	13	5	38.5	7	53.8	1	7.7
Mercuric chloride	Kyan	None	---[e]	12	4	33.3	6	50.0	2	16.7
			Maple							
Creosote	Full cell	None	10.7	50	50	100.0	---	---	---	---
Creosote	Full cell	Flat	12.2	49	49	100.0	---	---	---	---
Creosote	Rueping	Flat	5.0	50	49	98.0	1	2.0	---	---
Creosote	Rueping	None	4.8	50	50	100.0	---	---	---	---
20% creosote, 80% zinc chloride	Card	None	14.7[f]	50	46	92.0	3	6.0	1	2.0
20% creosote, 80% zinc chloride	Card	Flat	17.3[f]	50	47	94.0	2	4.0	1	2.0
Semi-refined paraffin oil	Full cell	Flat	11.1	50	45	90.0	2	4.0	3	6.0
Semi-refined paraffin oil	Full cell	None	14.3	49	45	91.8	2	4.1	2	4.1
Zinc chloride-creosote	Two movement	Flat	16.4[g]	50	38	76.0	7	14.0	5	10.0
Zinc chloride-creosote	Two movement	None	15.1[g]	50	25	50.0	22	44.0	3	6.0
Zinc chloride	Burnett	None	20.1[h]	49	1	2.0	26	53.1	22	44.9
Zinc chloride	Burnett	Flat	20.1[h]	50	20	40.0	21	42.0	9	18.0
Untreated[3]		None	---	50	---	---	50	100.0	---	---
Untreated[4]		Flat	---	50	---	---	50	100.0	---	---

C. M. St. P. & P. Test Track at Hartford (Continued)

Ties Set October, 1911

Preservative	Process	Tie plates	Average absorption lb. per cu. ft.	Ties in test No.	Condition of ties—October, 1939: Serviceable Number	Serviceable Per cent	Removed: Mainly for decay Number	Mainly for decay Per cent	Removed: Mainly for causes other than decay[a] and unknown causes[b] Number	Per cent
Red oak										
Creosote	Full cell	None	11.2	52	51	98.1			1	1.9
Creosote	Full cell	Flat	10.9	50	48	96.0			2	4.0
Creosote	Rueping	Flat	5.0	50	48	96.0	1	2.0	1	2.0
Creosote	Rueping	None	5.7	50	47	94.0	2	4.0	1	2.0
20% creosote, 80% zinc chloride	Card	None	15.5[f]	50	41	82.0	2	4.0	7	14.0
20% creosote, 80% zinc chloride	Card	Flat	15.2[f]	50	50	100.0				
Semi-refined paraffin oil	Full cell	Flat	8.4	50	45	90.0	4	8.0	1	2.0
Semi-refined paraffin oil	Full cell	None	6.2	49	33	67.3	7	14.3	9	18.4
Zinc chloride-creosote	Two movement	Flat	14.7[g]	50	40	80.0	5	10.0	5	10.0
Zinc chloride-creosote	Two movement	None	16.0[g]	50	30	60.0	13	26.0	7	14.0
Zinc chloride	Burnett[c]	Flat	12.5[d]	206	7	3.4	133	64.6	66	32.0
Zinc chloride	Burnett[c]	Ribbed	12.5[d]	53	4	7.6	30	56.6	19	35.8
Zinc chloride	Burnett	None	15.8[i]	50	19	38.0	22	44.0	9	18.0
Zinc chloride	Burnett	Flat	16.4[i]	50	34	68.0	9	18.0	7	14.0
Untreated[5]		None		50			50	100.0		
Untreated[6]		Flat		50			50	100.0		

Note: This test is being conducted in co-operation with the United States Forest Products Laboratory.

[a] Rail cutting, splitting, etc.

[b] Ties not available for examination after removal to determine the cause of removal.

[c] Obtained from regular stock of C. M. & St. P. & P.

[d] 4% zinc chloride solution.

[e] Steeping treatment in cold mercuric chloride solution—absorption figures not available.

[f] Emulsion of 80 parts of 3% zinc chloride solution and 20 parts of creosote by volume at approximately 70 deg. F.

[g] 3% zinc chloride solution plus creosote. Treatment consisted of bath in hot creosote for 30 minutes at atmospheric pressure followed by pressure treatment with 3% zinc chloride solution.

[h] 2½% zinc chloride solution.

[i] 3% zinc chloride solution.

[1] Average life 15.6 years.

[2] Average life 13.4 years.

[3] Average life 6.4 years.

[4] Average life 7.8 years.

[5] Average life 8.7 years.

[6] Average life 9.2 years.

CONDITION OF EXPERIMENTAL TIES IN THE CHICAGO, MILWAUKEE, ST. PAUL & PACIFIC TEST TRACK NEAR THE FAIR GROUNDS, MADISON, WIS.

Condition at an Inspection in September, 1939

Species	Preservative	Average absorption lb. per cu. ft.	Ties in test No.	Serviceable		Removed: Mainly for decay		Removed: Mainly for causes other than decay[a]	
				Number	Per cent	Number	Per cent	Number	Per cent
Ties set 1916—23 years service									
Red oak	Zinc chloride[b]	0.55	163			157	96.3	6	3.7
Red oak	25% creosote & 75% gas oil	10.20	75	61	81.4	7	9.3	7	9.3
Red oak	10% creosote & 90% gas oil	10.00	98	66	67.3	8	8.2	24	24.5
Ties set 1917—22 years service									
Douglas fir[c]	Creosote	11.50	28	9	32.2	1	3.6	18	64.2
Douglas fir[c]	Untreated[d]		38			36	94.7	2	5.3
Douglas fir[c]	Untreated		47	1	2.1	38	80.9	8	17.0
Western larch	Untreated[e]		44			43	97.7	1	2.3
White oak	Untreated		95	1	1.1	92	96.8	2	2.1
Red oak	Sodium fluoride	0.52	99	12	12.1	72	72.8	15	15.1
Red oak	Water gas tar	9.79	100	100	100.0				
Ties set 1919—20 years service									
Douglas fir[c]	Zinc chloride	0.52	105	3	2.9	55	52.4	47	44.7
Western larch	Zinc chloride[f]	0.48	95			33	34.7	62	65.3
Red oak	50% c. t. creo. & 50% w. t. creo.	9.50	62	46	74.2	9	14.5	7	11.3
Slippery elm	50% c. t. creo. & 50% w. t. creo.	10.85	25	17	68.0	2	8.0	6	24.0
Butternut	50% c. t. creo. & 50% w. t. creo.	9.00	9	1	11.1	7	77.8	1	11.1
White oak	50% c. t. creo. & 50% w. t. creo.	7.30	1	1	100.0				
Cherry	50% c. t. creo. & 50% w. t. creo.	10.50	3	3	100.0				
Red oak	Wood tar creosote	10.08	100	32	32.0	44	44.0	24	24.0
Ties set 1921—18 years service									
Red oak	Low temperature coal tar oil	10.30	100	98	98.0	1	1.0	1	1.0
Red oak	20% coal tar and 80% low temp. coal tar oil[g]	10.50	100	100	100.0				
Red oak	Vertical retort c. t. creo.	9.60	100	100	100.0				
Red oak	Pintsch gas tar	10.50	100	98	98.0	2	2.0		
Ties set 1927—12 years service									
Jack pine	Zinc chloride	0.52	381	328	86.1	41	10.8	12	3.1

Note: This test is being conducted in co-operation with the United States Forest Products Laboratory.

[a] Rail cutting, splitting, etc.

[b] Average life—16.8 years.

[c] Western Washington and Oregon type.

[d] Switch ties—average life 6.5 years.

[e] Average life—10.7 years.

[f] Average life—16.2 years.

[g] Reported as 50% tar and 50% low temp. coal tar oil prior to 1935.

CONDITION OF EXPERIMENTAL TIES IN MAIN-LINE TRACK OF THE UNION PACIFIC, NEAR LARAMIE, WYO., AFTER ABOUT 12 YEARS SERVICE

Ties Set October, 1927

Inspected May, 1939

Species	Form of ties	No. of ties in test	Good		Checked, split, plate worn, etc. (No decay)		Decaying		Removed[a]		Not inspected	
			Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
			Preservative—zinc chloride									
Engelmann spruce (made from sound timber)	Hewed	100	55	55.0	37	37.0	1	1.0	5	5.0	2[b]	2.0
Lodgepole pine (containing stump rot)	Sawed & hewed	100	68	68.0	27	27.0			3	3.0	2[b]	2.0
Lodgepole pine (containing red rot or incipient decay)	Sawed & hewed	100	54	54.0	41	41.0	1	1.0	4	4.0		
Lodgepole pine (made from sound dead timber)	Hewed	100	73	73.0	23	23.0	1	1.0	3	3.0		
Lodgepole pine (made from sound live timber)	Hewed	100	71	71.0	24	24.0			2	2.0	3[c]	3.0

Note: This test is being conducted in co-operation with Region 2, United States Forest Service, Denver, Colorado.

General information
Ballast —Gravel
Tie plates —Yes
Spikes —Cut
Traffic —Heavy
Track curvature—O degrees
Treatment —Preliminary steaming at 20 lb. for 1 hr. 45 min. followed by vacuum of 20 in. for 1 hr 25 min. Solution applied at pressure of 163 lb. and temperature of 180 deg. F. for 3 hours. 40 min. Average absorption for each group—.41 lb. dry zinc chloride per cu. ft.

[a] Probably removed on account of mechanical damage.
[b] Covered with ballast.
[c] Under crossing.

THE ATCHISON, TOPEKA & SANTA FE, CLEVELAND, TEXAS, TEST TRACK

Tabulation Showing Actual Performance to January 1, 1939, in Track, and Estimated Total Life Based on Tie-Life Curve, of the Forest Products Laboratory at Madison, Wis., of Ties in Cleveland, Tex., Test Track of the Santa Fe Railway, Treated with Zinc-Petroleum, Straight Zinc Chloride, and Creosote-Petroleum Mixture

Amount zinc chloride per cu. ft.	Year inserted	Original number inserted	Total removed	Per cent removed	Average life in track to 1–1–39	Expected average life #
Hewn Pine Ties—Table 1—Zinc-Petroleum Treatment						
¼ to ½ lb.	1915	17	17	100.00	12.35	*
½ to ¾	1915	14	14	100.00	13.36	*
¾ and over	1915	1	1	100.00	12.00	*
Total		32	32	100.00	12.78	*
Sawn Pine Ties—Table 2—Zinc-Petroleum Treatment						
Up to ¼ lb.	1915	22	19	86.36	17.82	19.33
¼ to ½	1915	50	44	88.00	17.02	19.01
½ to ¾	1915	23	23	100.00	15.09	*
¾ and over	1915	3	3	100.00	11.67	*
Total		98	89	90.82	16.48	*
Hewn Oak Ties—Table 3—Zinc-Petroleum Treatment						
Up to ¼ lb.	1915	2	2	100.00	17.00	*
¼ to ½	1915	23	22	95.65	16.61	*
½ to ¾	1915	3	3	100.00	16.00	*
Total		28	27	96.43	16.57	*
Sawn Oak Ties—Table 4—Zinc-Petroleum Treatment						
¼ to ½ lb.	1915	7	7	100.00	13.86	*
½ to ¾	1915	4	4	100.00	14.00	*
Total		11	11	100.00	13.91	*
Hewn Gum Ties—Table 5—Zinc-Petroleum Treatment						
¼ to ½ lb.	1915	2	2	100.00	11.00	*
½ to ¾	1915	3	3	100.00	15.33	*
Total		5	5	100.00	13.60	*
Sawn Gum Ties—Table 6—Zinc-Petroleum Treatment						
Up to ¼ lb.	1915	9	9	100.00	15.22	*
¼ to ½	1915	16	14	87.50	16.19	19.01
½ to ¾	1915	18	15	83.33	17.78	19.66
¾ and over	1915	7	6	85.71	19.29	19.33
Total		50	44	88.00	17.02	19.01
Hewn Elm Ties—Table 7—Zinc Petroleum Treatment						
Up to ¼ lb.	1915	1	1	100.00	13.00	*
¼ to ½	1915	1	1	100.00	13.00	*
½ to ¾	1915	6	5	83.33	16.67	19.66
¾ and over	1915	2	2	100.00	12.00	*
Total		10	9	90.00	15.00	18.70
All Woods—Table 8—Zinc-Petroleum Treatment						
Up to ¼ lb.	1915	34	31	91.18	16.94	*
¼ to ½	1915	116	107	92.24	15.81	*
½ to ¾	1915	71	67	94.37	15.41	*
¾ and over	1915	13	12	92.31	15.85	*
Total		234	217	92.74	15.85	*

# Based on Forest Products Laboratory curve.

* Percent renewed is beyond the limits of the Forest Products Laboratory curve for treated ties.

A. T. & S. F. CLEVELAND TEST TRACK (Continued)

Amount zinc chloride per cu. ft.	Year inserted	Original number inserted	Total removed	Per cent removed	Average life in track to 1–1–39	Expected average life #
Sawn Pine Ties—Table 9—Straight Zinc Chloride Treatment						
Up to ¼ lb.	1915	7	3	42.86	20.14	25.84
¼ to ½	1915	55	51	92.73	13.93	*
½ to ¾	1915	25	25	100.00	11.28	*
¾ and over	1915	6	6	100.00	9.67	*
Total		93	85	91.40	13.41	*
Sawn Gum Ties—Table 10—Straight Zinc Chloride Treatment						
Up to ¼ lb.	1915	4	4	100.00	14.50	*
¼ to ½	1915	8	8	100.00	13.25	*
½ to ¾	1915	12	12	100.00	13.50	*
¾ and over	1915	2	2	100.00	14.00	*
Total		26	26	100.00	13.23	*
All Woods—Table 11—Straight Zinc Chloride Treatment						
Up to ¼ lb.	1915	11	7	63.64	18.09	22.55
¼ to ½	1915	63	59	93.65	13.84	*
½ to ¾	1915	37	37	100.00	12.00	*
¾ and over	1915	8	8	100.00	10.75	*
Total		119	111	93.28	13.45	*
SUMMARY Zinc Chloride and Zinc-Petroleum Treatments—Table 12						
Up to ¼ lb.	1915	45	38	84.44	17.22	19.49
¼ to ½	1915	179	166	92.74	15.12	*
½ to ¾	1915	108	104	96.30	14.24	*
¾ and over	1915	21	20	95.24	13.90	*
Total		353	328	92.92	15.05	*
Hewn Pine Ties—Table 13—Zinc-Petroleum Treatment						
No steam	1915	32	32	100.00	12.78	*
Sawn Pine Ties—Table 14—Zinc Petroleum Treatment						
No steam	1915	30	25	83.33	18.67	19.66
20 lb.—3 hr.	1915	19	19	100.00	13.16	*
30 lb.—2 hr.	1915	49	45	91.84	16.43	*
Total		98	89	90.82	16.48	*
Hewn Oak Ties—Table 15—Zinc-Petroleum Treatment						
No steam	1915	28	27	96.43	16.57	*
Sawn Oak Ties—Table 16—Zinc-Petroleum Treatment						
No steam	1915	10	10	100.00	14.00	*
20 lb.—3 hr.	1915	1	1	100.00	13.00	*
Total		11	11	100.00	13.91	*
Hewn Gum Ties—Table 17—Zinc-Petroleum Treatment						
No steam	1915	5	5	100.00	13.60	*
Sawn Gum Ties—Table 18—Zinc-Petroleum Treatment						
No steam	1915	41	35	85.37	17.41	19.33
20 lb.—3 hr.	1915	3	3	100.00	14.33	*
30 lb.—3 hr.	1915	6	6	100.00	15.67	*
Total		50	44	88.00	17.02	19.01

# Based on Forest Products Laboratory curve.

* Percent renewed is beyond the limits of the Forest Products Laboratory curve for treated ties.

A. T. & S. F. CLEVELAND TEST TRACK (Continued)

Amount zinc chloride per cu. ft.	Year inserted	Original number inserted	Total removed	Per cent removed	Average life in track to 1-1-39	Expected average life #
Hewn Elm Ties—Table 19—Zinc-Petroleum Treatment						
No steam	1915	10	9	90.00	15.00	18.70
All Woods—Table 20—Zinc-Petroleum Treatment						
No steam	1915	156	143	91.67	16.06	*
20 lb.—3 hr.	1915	23	23	100.00	13.30	*
20 lb.—2 hr.	1915	49	45	91.84	16.43	*
30 lb.—3 hr.	1915	6	6	100.00	15.67	*
Total		234	217	92.74	15.85	*
Sawn Pine Ties—Table 21—Straight Zinc Chloride Treatment						
No steam	1915	10	9	90.00	12.70	18.70
20 lb.—3 hr.	1915	10	9	90.00	14.80	18.70
30 lb.—2 hr.	1915	73	67	91.78	13.32	*
Total		93	85	91.40	13.41	*
Sawn Gum Ties—Table 22—Straight Zinc Chloride Treatment						
No steam	1915	9	9	100.00	14.11	*
30 lb.—2 hr.	1915	17	17	100.00	13.35	*
Total		26	26	100.00	13.23	*
All woods—Table 23—Straight Zinc Chloride Treatment						
No steam	1915	19	18	94.74	13.37	*
20 lb.—3 hr.	1915	10	9	90.00	14.80	18.70
30 lb.—2 hr.	1915	90	84	93.33	13.32	*
Total		119	111	93.28	13.45	*
Hewn Pine Ties—Table 24—Zinc-Petroleum Treatment						
¼ to ½ lb.	1917	1	1	100.00	8.00	*
½ to ¾	1917	5	5	100.00	12.40	*
¾ and over	1917	14	14	100.00	13.79	*
Total		20	20	100.00	13.15	*
Sawn Pine Ties—Table 25—Zinc-Petroleum Treatment						
¼ to ½ lb.	1917	22	4	18.18	20.50	29.17
½ to ¾	1917	14	3	21.43	20.29	28.00
¾ and over	1917	4	3	75.00	20.00	19.09
Total		40	10	25.00	20.38	26.92
Hewn Oak Ties—Table 26—Zinc-Petroleum Treatment						
Up to ¼ lb.	1917	2	2	100.00	11.50	*
¼ to ½	1917	18	17	94.44	12.89	*
Total		20	19	95.00	12.75	*
Hewn Gum Ties—Table 27—Zinc-Petroleum Treatment						
Up to ¼ lb.	1917	1	0	0.00	21.00	*
¼ to ½	1917	4	3	75.00	19.00	19.09
½ to ¾	1917	3	3	100.00	13.00	*
¾ and over	1917	12	10	83.33	15.25	17.95
Total		20	16	80.00	15.95	18.42

# Based on Forest Products Laboratory curve.

* Percent renewed is beyond the limits of the Forest Products Laboratory curve for treated ties.

A. T. & S. F. CLEVELAND TEST TRACK (Continued)

Amount zinc chloride per cu. ft.	Year in-serted	Original number inserted	Total removed	Per cent removed	Average life in track to 1-1-39	Expected average life #
All Woods—Table 28—Zinc-Petroleum Treatment						
Up to ¼ lb.	1917	3	2	66.67	14.67	20.19
¼ to ½	1917	45	25	55.56	17.04	21.65
½ to ¾	1917	22	11	50.00	17.50	22.58
¾ and over	1917	30	27	90.00	15.20	17.07
Total		100	65	65.00	16.52	20.39
Hewn Pine Ties—Table 29—Straight Zinc Chloride Treatment						
Up to ¼ lb.	1917	1	1	100.00	8.00	*
¼ to ½	1917	4	4	100.00	8.00	*
½ to ¾	1917	3	3	100.00	9.00	*
¾ and over	1917	12	12	100.00	8.50	*
Total		20	20	100.00	8.45	*
Sawn Pine Ties—Table 30—Straight Zinc Chloride Treatment						
Up to ¼ lb.	1917	1	1	100.00	8.00	*
¼ to ½	1917	15	7	46.67	19.40	23.08
½ to ¾	1917	22	18	81.82	14.86	18.10
¾ and over	1917	2	2	100.00	13.50	*
Total		40	28	70.00	16.33	19.81
Hewn Oak Ties—Table 31—Straight Zinc Chloride Treatment						
Up to ¼ lb.	1917	5	5	100.00	10.20	*
¼ to ½	1917	15	15	100.00	9.47	*
Total		20	20	100.00	9.65	*
Hewn Gum Ties—Table 32—Straight Zinc Chloride Treatment						
Up to ¼ lb.	1917	1	1	100.00	8.00	*
¼ to ½	1917	7	7	100.00	16.14	*
½ to ¾	1917	6	6	100.00	15.67	*
¾ and over	1917	6	6	100.00	12.67	*
Total		20	20	100.00	14.55	*
All Woods—Table 33—Straight Zinc Chloride Treatment						
Up to ¼ lb.	1917	8	8	100.00	9.38	*
¼ to ½	1917	41	33	80.49	14.10	18.42
½ to ¾	1917	31	27	87.10	14.45	17.50
¾ and over	1917	20	20	100.00	10.25	*
Total		100	88	88.00	13.06	17.36
Hewn Pine Ties—Table 34—Zinc Petroleum Treatment						
No steam	1917	5	5	100.00	12.40	*
20 lb.—2 hr.	1917	5	5	100.00	13.80	*
20 lb.—4 hr.	1917	5	5	100.00	15.00	*
20 lb.—6 hr.	1917	5	5	100.00	11.40	*
Total		20	20	100.00	13.15	*
Sawn Pine Ties—Table 35—Zinc Petroleum Treatment						
No steam	1917	10	2	20.00	20.30	28.38
20 lb.—2 hr.	1917	10	2	20.00	20.70	28.38
20 lb.—4 hr.	1917	10	3	30.00	20.10	25.93
20 lb.—6 hr.	1917	10	3	30.00	20.40	25.93
Total		40	10	25.00	20.38	26.92

# Based on Forest Products Laboratory curve.

* Percent renewed is beyond the limits of the Forest Products Laboratory curve for treated ties.

A. T. & S. F. CLEVELAND TEST TRACK (Continued)

Amount zinc chloride per cu. ft.	Year inserted	Original number inserted	Total removed	Per cent removed	Average life in track to 1-1-39	Expected average life #
Hewn Oak Ties—Table 36—Zinc Petroleum Treatment						
No steam	1917	5	4	80.00	14.20	18.42
20 lb.—2 hr.	1917	5	5	100.00	13.20	*
20 lb.—4 hr.	1917	5	5	100.00	8.80	*
20 lb.—6 hr.	1917	5	5	100.00	14.80	*
Total		20	19	95.00	12.75	*
Hewn Gum Ties—Table 37—Zinc Petroleum Treatment						
No steam	1917	5	3	60.00	17.60	21.21
20 lb.—2 hr.	1917	5	5	100.00	18.20	*
20 lb.—4 hr.	1917	5	4	80.00	12.60	18.42
20 lb.—6 hr.	1917	5	4	80.00	15.40	18.42
Total		20	16	80.00	15.95	18.42
All Woods—Table 38—Zinc Petroleum Treatment						
No steam	1917	25	14	56.00	16.96	21.65
20 lb.—2 hr.	1917	25	17	68.00	17.32	20.00
20 lb.—4 hr.	1917	25	17	68.00	15.32	20.00
20 lb.—6 hr.	1917	25	17	68.00	16.48	20.00
Total		100	65	65.00	16.52	20.39
Hewn Pine Ties—Table 39—Straight Zinc Chloride Treatment						
No steam	1917	5	5	100.00	8.00	*
20 lb.—2 hr.	1917	5	5	100 00	9.40	*
20 lb.—4 hr.	1917	5	5	100.00	8.40	*
20 lb.—6 hr.	1917	5	5	100.00	8.00	*
Total		20	20	100.00	8.45	*
Sawn Pine Ties—Table 40—Straight Zinc Chloride Treatment						
No steam	1917	10	5	50.00	16.80	22.58
20 lb.—2 hr.	1917	10	7	70.00	16.10	19.81
20 lb.—4 hr.	1917	10	7	70.00	16.30	19.81
20 lb.—6 hr.	1917	10	9	90.00	16.10	17.07
Total		40	28	70.00	16.33	19.81
Hewn Oak Ties—Table 41—Straight Zinc Chloride Treatment						
No steam	1917	5	5	100.00	10.20	*
20 lb.—2 hr.	1917	5	5	100.00	9.80	*
20 lb.—4 hr.	1917	5	5	100.00	9.40	*
20 lb.—6 hr.	1917	5	5	100.00	9.20	*
Total		20	20	100.00	9.65	*
Hewn Gum Ties—Table 42—Straight Zinc Chloride Treatment						
No steam	1917	5	5	100.00	15.40	*
20 lb.—2 hr.	1917	5	5	100.00	13.20	*
20 lb.—4 hr.	1917	5	5	100.00	15.60	*
20 lb.—6 hr.	1917	5	5	100.00	14.00	*
Total		20	20	100.00	14.55	*
All Woods—Table 43—Straight Zinc Chloride Treatment						
No steam	1917	25	20	80.00	13.44	18.42
20 lb.—2 hr.	1917	25	22	88.00	12.92	17.36
20 lb.—4 hr.	1917	25	22	88.00	13.20	17.36
20 lb.—6 hr.	1917	25	24	96.00	12.68	*
Total		100	88	88.00	13.06	17.36

# Based on Forest Products Laboratory curve.

* Percent renewed is beyond the limits of the Forest Products Laboratory curve for treated ties.

A. T. & S. F. CLEVELAND TEST TRACK (Continued)

Kind of wood	Year inserted	Original number inserted	Total removed	Per cent removed	Average life in track to 1-1-39	Expected average life #
SUMMARY—Table 1—Creosote-Petroleum Mixture Treatment						
Hewn sap pine	1912	86	72	83.72	18.35	21.67
	1913	116	80	68.97	18.94	23.58
Hn. loblolly pine	1912	78	72	92.31	16.81	*
Hn. Shortleaf pine	1912	29	22	75.86	20.41	23.21
Hn. longleaf pine	1912	22	18	81.82	19.37	22.03
Hn. heart pine	1912	122	61	50.00	22.57	28.26
	1913	116	32	27.59	23.14	32.05
Hewn oak	1912	50	41	82.00	17.56	22.03
Hewn gum	1912	80	35	43.75	22.50	29.55
	1913	116	14	12.07	24.39	38.46
Total		815	447	54.85	21.35	----------

Amount of Mixture Per cu. ft.	Year Inserted	Original Number inserted	Total removed	Per cent removed	Average Life in Track to 1-1-39	Expected average life #
Hewn Sap Pine—Table 2—Creosote-Petroleum Mixture Treatment						
Less than 5 lb.	1912	9	8	88.89	17.22	20.80
	1913	2	2	100.00	20.50	*
5 to 7 lb.	1912	32	22	68.75	20.75	24.53
	1913	41	32	78.05	18.49	21.93
7 to 8 lb.	1912	4	2	50.00	21.00	28.26
	1913	36	25	69.44	19.19	23.58
8 to 10 lb.	1912	8	6	75.00	19.25	23.42
	1913	32	23	71.88	18.28	22.94
10 to 15 lb.	1912	32	29	90.63	16.16	*
	1913	5	2	40.00	22.80	29.41
15 lb. & over	1912	1	1	100.00	12.00	*
Total		202	152	75.25	19.26	----------
Hewn Loblolly Pine—Table 3—Creosote-Petroleum Mixture Treatment						
10 to 15 lb.	1912	2	2	100.00	18.00	*
15 lb. & over	1912	76	70	92.11	16.78	*
Total		78	72	92.31	16.81	*
Hewn Shortleaf Pine—Table 4—Creosote-Petroleum Mixture Treatment						
8 to 10 lb.	1912	1	0	0.00	26.00	*
10 to 15 lb.	1912	12	11	91.67	19.92	*
15 lb. & over	1912	16	11	68.75	20.44	24.53
Total		29	22	75.86	20.41	----------
Hewn Longleaf Pine—Table 5—Creosote-Petroleum Mixture Treatment						
Less than 5 lb.	1912	3	3	100.00	13.33	*
5 to 7 lb.	1912	3	1	33.33	23.00	32.10
7 to 8 lb.	1912	4	4	100.00	14.50	*
8 to 10 lb.	1912	4	3	75.00	18.50	23.42
10 to 15 lb.	1912	7	6	85.71	23.29	21.31
15 lb. & over	1912	1	1	100.00	22.00	*
Total		22	18	81.82	19.37	----------

# Based on Forest Products Laboratory curve.

* Percent renewed is beyond the limits of the Forest Products Laboratory curve for treated ties.

A. T. & S. F. CLEVELAND TEST TRACK (Continued)

Amount of mixture per cu. ft.	Year inserted	Original number inserted	Total removed	Per cent removed	Average life in track to 1-1-39	Expected average life #
Hewn Heart Pine—Table 6—Creosote-Petroleum Mixture Treatment						
Less than 5 lb.......	1912	3	3	100.00	22.67	*
	1913	5	2	40.00	23.00	29.41
5 to 7 lb..........	1912	12	6	50.00	23.75	28.26
	1913	39	14	35.90	22.64	30.12
7 to 8 lb..........	1912	10	5	50.00	22.90	28.26
	1913	35	6	17.14	23.97	35.71
8 to 10 lb..........	1912	31	16	51.61	22.29	27.66
	1913	29	10	34.48	22.31	30.86
10 to 15 lb..........	1912	50	31	62.00	21.28	25.74
	1913	8	0	0.00	25.00	*
15 lb. & over........	1912	16	2	12.50	25.81	39.39
Total................		238	95	39.92	23.32	....
Hewn Oak—Table 7—Creosote-Petroleum Mixture Treatment						
Less than 5 lb.......	1912	34	31	91.18	15.50	*
5 to 7 lb..........	1912	14	10	71.43	21.36	24.07
7 to 8 lb..........	1912	1	0	0.00	26.00	*
8 to 10 lb..........	1912	1	0	0.00	26.00	*
Total................		50	41	82.00	17.56	....
Hewn Gum—Table 8—Creosote-Petroleum Mixture Treatment						
Less than 5 lb.......	1912	14	10	71.43	18.64	24.07
	1913	7	1	14.29	24.00	37.31
5 to 7 lb..........	1912	18	8	44.44	22.06	29.55
	1913	27	6	22.22	23.56	34.25
7 to 8 lb..........	1912	11	6	54.55	21.73	27.08
	1913	26	2	7.69	24.77	*
8 to 10 lb..........	1912	18	4	22.22	25.67	35.62
	1913	40	2	5.00	24.97	*
10 to 15 lb..........	1912	17	6	35.29	23.71	31.71
	1913	16	1	6.25	24.13	*
15 lb. & over........	1912	2	1	50.00	19.00	28.26
Total................		196	47	23.98	24.23	....
All Woods—Table 9—Creosote-Petroleum Mixture Treatment						
Less than 5 lb.......	1912	63	55	87.30	16.68	21.14
	1913	14	5	35.71	23.14	30.12
5 to 7 lb..........	1912	79	47	59.49	21.70	26.53
	1913	107	52	48.60	21.28	27.47
7 to 8 lb..........	1912	30	17	56.67	21.20	26.80
	1913	97	33	34.02	22.41	30.86
8 to 10 lb..........	1912	63	29	46.03	22.75	29.21
	1913	101	35	34.65	22.09	30.49
10 to 15 lb..........	1912	120	84	70.00	20.20	24.30
	1913	29	4	13.79	24.07	37.31
15 lb. & over........	1912	112	86	76.79	18.68	23.01
	1912	467	318	68.09	20.01	24.76
	1913	348	129	37.07	22.14	30.12
Total................		815	447	54.85	21.35	....
Hewn Sap Pine—Table 10—Creosote-Petroleum Mixture Treatment						
Amount of creosote only						
Less than 1 lb.......	1912	8	7	87.50	16.88	20.97
	1913	1	1	100.00	17.00	*
1 to 2 lb............	1912	33	26	78.79	19.33	22.61
	1913	59	37	62.71	18.58	24.75
2 to 3 lb............	1912	44	34	77.27	18.20	23.01
	1913	45	37	82.22	19.76	21.19
3 to 4 lb............	1912	1	1	100.00	12.00	*
	1913	11	9	81.82	17.00	21.19
Total................		202	152	75.25	19.26	....

# Based on Forest Products Laboratory curve.

* Percent renewed is beyond the limits of the Forest Products Laboratory curve for treated ties.

A. T. & S. F. CLEVELAND TEST TRACK (Continued)

Amount of creosote per cu. ft.	Year in-serted	Original number inserted	Total removed	Per cent removed	Average life in track to 1-1-39	Expected average life #
Hewn Loblolly Pine—Table 11—Creosote-Petroleum Mixture Treatment						
3 to 4 lb.	1912	6	6	100.00	13.50	*
4 to 5 lb.	1912	31	27	87.10	15.77	21.14
5 to 6 lb.	1912	24	22	91.67	18.58	*
6 to 7 lb.	1912	13	13	100.00	17.46	*
7 to 8 lb.	1912	4	4	100.00	17.00	*
Total		78	72	92.31	16.81	*
Hewn Shortleaf Pine—Table 12—Creosote-Petroleum Mixture Treatment						
2 to 3 lb.	1912	2	1	50.00	21.00	28.26
3 to 4 lb.	1912	8	7	87.50	20.68	20.97
4 to 5 lb.	1912	8	8	100.00	18.38	*
5 to 6 lb.	1912	9	5	55.56	21.33	27.08
6 to 7 lb.	1912	2	1	50.00	23.00	28.26
Total		29	22	75.86	20.41	----------
Hewn Longleaf Pine—Table 13—Creosote-Petroleum Mixture Treatment						
1 to 2 lb.	1912	7	6	85.71	14.43	21.31
2 to 3 lb.	1912	7	4	57.14	21.71	26.80
3 to 4 lb.	1912	6	6	100.00	21.67	*
4 to 5 lb.	1912	1	1	100.00	21.00	*
6 to 7 lb.	1912	1	1	100.00	22.00	*
Total		22	18	81.82	19.37	----------
Hewn Heart Pine—Table 14—Creosote-Petroleum Mixture Treatment						
Less than 1 lb.	1912	1	1	100.00	25.00	*
	1913	2	1	50.00	21.50	27.17
1 to 2 lb.	1912	49	27	55.10	22.18	27.08
	1913	61	20	32.79	22.28	30.86
2 to 3 lb.	1912	49	31	63.27	21.35	25.74
	1913	43	11	25.58	24.00	32.89
3 to 4 lb.	1912	22	4	18.18	25.73	37.14
	1913	10	0	0.00	25.00	*
4 to 5 lb.	1912	1	0	0.00	26.00	*
Total		238	95	39.92	23.32	----------
Hewn Oak—Table 15—Creosote-Petroleum Mixture Treatment						
Less than 1 lb.	1912	34	31	91.18	15.50	*
1 to 2 lb.	1912	16	10	62.50	21.94	25.74
Total		50	41	82.00	17.56	----------
Hewn Gum—Table 16—Creosote-Petroleum Mixture Treatment						
Less than 1 lb.	1912	10	8	80.00	16.00	22.41
	1913	4	1	25.00	23.25	32.89
1 to 2 lb.	1912	44	18	40.91	23.30	30.23
	1913	59	5	8.47	24.44	*
2 to 3 lb.	1912	23	7	30.43	24.04	37.14
	1913	34	5	14.71	24.62	36.76
3 to 4 lb.	1912	3	1	33.33	21.33	32.10
	1913	19	2	10.53	24.16	39.06
Total		196	47	23.98	24.23	----------

# Based on Forest Products Laboratory curve.

* Percent renewed is beyond the limits of the Forest Products Laboratory curve for treated ties.

A. T. & S. F. CLEVELAND TEST TRACK (Continued)

All Woods—Table 17—Creosote-Petroleum Mixture Treatment

Amount of creosote per cu. ft.	Year inserted	Original number inserted	Total removed	Per cent removed	Average life in track to 1-1-39	Expected average life #
Less than 1 lb.	1912	53	48	90.57	15.85	*
	1913	7	2	28.57	22.86	32.05
1 to 2 lb.	1912	149	87	58.39	21.49	26.53
	1913	179	62	34.64	21.77	30.49
2 to 3 lb.	1912	125	77	61.60	20.75	25.74
	1913	122	53	43.44	22.61	28.74
3 to 4 lb.	1912	46	25	54.35	22.13	27.37
	1913	40	11	27.50	22.40	32.05
4 to 5 lb.	1912	41	36	87.80	16.66	20.97
5 to 6 lb.	1912	33	27	81.82	19.33	22.03
6 to 7 lb.	1912	16	15	93.75	18.44	*
7 to 8 lb.	1912	4	4	100.00	17.00	*
	1912	467	318	68.09	20.01	24.76
	1913	348	129	37.07	22.14	30.12
Total		815	447	54.85	21.35	

Hewn Sap Pine—Table 18—Creosote-Petroleum Mixture Treatment

Symbol	Proportion of mixture	Year inserted	Original number inserted	Total removed	Percent removed	Average life in track to 1-1-39	Expected average life #
RBM	1 creo to 2 Beaumont	1913	29	26	89.66	17.00	19.84
RBM	1 creo to 4 Beaumont	1912	28	22	78.57	18.64	22.61
		1913	29	12	41.38	21.97	29.07
ROK	1 creo to 2 Oklahoma	1912	18	10	55.56	22.89	27.08
		1913	29	22	75.86	21.31	22.32
ROK	1 creo to 4 Oklahoma	1913	29	24	82.76	15.21	21.01
OC	1 creo to 4 Oklahoma	1912	40	36	90.00	16.30	20.63
Total			202	152	75.25	19.26	

Hewn Loblolly Pine—Table 19—Creosote-Petroleum Mixture Treatment

Symbol	Proportion of mixture	Year inserted	Original number inserted	Total removed	Percent removed	Average life in track to 1-1-39	Expected average life #
3BC	1 creo to 3 Beaumont	1912	25	21	84.00	17.28	21.67
2BC	1 creo to 2 Beaumont	1912	15	15	100.00	19.13	*
OC	1 creo to 4 Oklahoma	1912	24	23	95.83	14.29	*
2EC	1 creo to 2 Ellinor	1912	14	13	92.86	17.79	*
Total			78	72	92.31	16.81	

Hewn Shortleaf Pine—Table 20—Creosote-Petroleum Mixture Treatment

Symbol	Proportion of mixture	Year inserted	Original number inserted	Total removed	Percent removed	Average life in track to 1-1-39	Expected average life #
3BC	1 creo to 3 Beaumont	1912	12	11	91.67	18.92	*
2BC	1 creo to 2 Beaumont	1912	9	7	77.78	21.22	22.81
2EC	1 creo to 2 Ellinor	1912	8	4	50.00	21.75	28.26
Total			29	22	75.86	20.41	

Hewn Longleaf Pine—Table 21—Creosote-Petroleum Mixture Treatment

Symbol	Proportion of mixture	Year inserted	Original number inserted	Total removed	Percent removed	Average life in track to 1-1-39	Expected average life #
3BC	1 creo to 3 Beaumont	1912	10	7	70.00	17.50	24.30
2BC	1 creo to 2 Beaumont	1912	6	5	83.33	24.50	21.85
2EC	1 creo to 2 Ellinor	1912	6	6	100.00	17.33	*
Total			22	18	81.82	19.37	

# Based on Forest Products Laboratory curve.

* Percent renewed is beyond the limits of the Forest Products Laboratory curve for treated ties.

A. T. & S. F. Cleveland Test Track (Continued)

Symbol	Proportion of mixture	Year inserted	Original number inserted	Total removed	Percent removed	Average life in track to 1-1-39	Expected average life #
	Hewn Heart Pine—Table 22—Creosote-Petroleum Mixture Treatment						
RBM	1 creo to 2 Beaumont	1912	8	2	25.00	25.63	34.21
		1913	29	6	20.69	24.07	34.25
RBM	1 creo to 4 Beaumont	1913	29	12	41.38	21.04	29.07
ROK	1 creo to 2 Oklahoma	1912	10	6	60.00	23.20	26.26
		1913	29	7	24.14	24.35	33.33
ROK	1 creo to 4 Oklahoma	1912	19	10	52.63	23.47	27.66
		1913	29	7	24.14	23.10	33.33
OC	1 creo to 4 Oklahoma	1912	85	45	52.94	21.96	27.66
	Total		238	95	39.92	23.32	--------
	Hewn Oak—Table 23—Creosote-Petroleum Mixture Treatment						
ROK	1 creo to 4 Oklahoma	1912	10	9	90.00	20.10	20.63
OC	1 creo to 4 Oklahoma	1912	40	32	80.00	16.93	22.41
	Total		50	41	82.00	17.56	--------
	Hewn Gum—Table 24—Creosote-Petroleum Mixture Treatment						
RBM	1 creo to 2 Beaumont	1912	8	4	50.00	25.25	28.26
		1913	29	8	27.59	23.76	32.05
RBM	1 creo to 4 Beaumont	1912	29	10	34.48	24.79	32.10
		1913	29	3	10.34	24.34	39.68
ROK	1 creo to 2 Oklahoma	1912	10	3	30.00	25.10	37.14
		1913	29	1	3.45	24.76	*
ROK	1 creo to 4 Oklahoma	1912	8	2	25.00	23.00	34.21
		1913	29	1	3.45	24.76	*
OC	1 creo to 4 Oklahoma	1912	25	15	60.00	17.84	26.26
	Total		196	47	23.98	24.23	--------
	All Woods—Table 25—Creosote-Petroleum Mixture Treatment						
3BC	1 creo to 3 Beaumont	1912	47	40	85.11	17.60	21.49
2BC	1 creo to 2 Beaumont	1912	38	27	71.05	21.92	24.07
RBM	1 creo to 2 Beaumont	1912	8	6	75.00	24.88	23.42
		1913	87	40	45.98	21.61	28.09
RBM	1 creo to 4 Beaumont	1912	57	32	56.14	21.77	27.08
		1913	87	27	31.03	22.45	31.25
ROK	1 creo to 2 Oklahoma	1912	38	19	50.00	23.55	28.26
		1913	87	30	34.48	23.47	30.86
ROK	1 creo to 4 Oklahoma	1912	37	21	56.76	22.46	26.80
		1913	87	32	36.78	21.02	30.12
OC	1 creo to 4 Oklahoma	1912	214	150	70.09	18.65	24.30
2EC	1 creo to 2 Ellinor	1912	28	23	82.14	18.82	22.03
		1912	467	318	68.09	20.01	24.76
		1913	348	129	37.07	22.14	30.12
	Total		815	447	54.85	21.35	--------

# Based on Forest Products Laboratory curve.

* Percent renewed is beyond the limits of the Forest Products Laboratory curve for treated ties.

REPORT OF TWENTY-NINTH ANNUAL INSPECTION OF CHICAGO, BURLINGTON & QUINCY EXPERIMENTAL TIES

The results of the 1938 inspection of the experimental ties in the tracks of the Chicago, Burlington & Quincy Railroad are given in the accompanying tabulations. These ties were laid in 1909 and 1910, some treated with coal-tar creosote by the full-cell process, with a retention of 10 to 12 lb. per cu. ft.; some with zinc chloride (Burnett process) with a retention of ½ lb. per cu. ft.; some with a mixture of these two preservatives (Card process), with an absorption of ½ lb. of zinc chloride and 3-lb. of creosote per cu. ft.; and some were untreated:

AVERAGE LIFE OF UNTREATED TIES IN YEARS

Kind	*Total Placed*	*Average Years*
Ash	116	5.1
Beech	208	5.0
Red birch	217	3.6
Chestnut	259	9.7
Cottonwood	86	2.9
Cypress	225	8.3
White elm	191	5.3
Hemlock	190	4.9
Hickory	110	5.5
Loblolly pine	248	5.3
Hard maple	122	4.7
Soft maple	125	3.6
White oak	125	11.1
Red oak	204	5.3
Pin oak	126	6.3
Poplar	126	5.3
Red gum	152	4.1
Sycamore	131	3.3
Tamarack	175	5.1
Tupelo gum	136	3.5
Total placed	3272	5.6

Summary of 1938 Inspection of Crosstie Test Tracks, Chicago, Burlington & Quincy—Results of 29 Years of Service

	Lines East						Lines West					
Process	Total placed	Total removed to date	Per cent removed account decay	Per cent removed account other causes	Actual average years life to date	Forest Products Laboratory curve estimated years average life	Total placed	Total removed to date	Per cent removed account decay	Per cent removed other causes	Actual average years life to date	Forest Products Laboratory curve estimated years average life
Straight creosote	2,046	1,347	22	44	23.6	28.	1,236	812	16	49	22.0	27.
Card	10,241	9,148	32	57	18.9	23.5	5,591	5,106	34	58	17.9	------
Burnett	1,578	1,556	54	44	16.1	------	910	906	49	50	14.9	------
Untreated	2,046	2,045	89	10	5.4	------	1,226	1,226	91	9	5.8	------
Total treated	13,865	12,051	33	53	19.2	24.5	7,737	6,824	33	55	18.2	24.
Grand total	15,911	14,096	------	------	------	------	8,963	8,050	------	------	------	------

Note: These percentages include only the ties placed in what are termed the thousand-tie lots on the various divisions.

1938 INSPECTION OF CROSS TIE TEST TRACK, CHICAGO, BURLINGTON & QUINCY—RESULTS OF 29 YEARS OF SERVICE

	Lines East						Lines West					
Process	Total placed	Total removed to date	Per cent removed account decay	Per cent removed account other causes	Estimated years average life	Actual years average life to date	Total placed	Total removed to date	Per cent removed account decay	Per cent removed account other causes	Estimated years average life	Actual years average life to date
						Ash						
Creosote	19	19	32	68	------	16.7	15	13	20	67	24.0	20.4
Card	289	272	20	74	------	18.8	103	96	22	72	------	18.1
Burnett	16	16	44	56	------	18.2	15	15	47	53	------	17.2
Untreated	70	70	99	1	------	5.1	46	46	100	------	------	5.3
						Beech						
Creosote	321	130	12	29	33.5	26.0	163	64	10	29	34.5	25.1
Card	807	779	45	51	------	17.7	418	401	41	55	------	17.2
Burnett	210	207	55	43	------	16.0	105	104	59	40	------	15.8
Untreated	134	134	98	2	------	4.6	74	74	93	7	------	5.4
						Birch						
Creosote	75	69	65	27	------	22.8	59	42	15	56	27.0	22.5
Card	715	659	40	52	------	18.1	360	345	35	61	------	18.0
Burnett	73	73	48	52	------	13.0	30	30	43	57	------	14.4
Untreated	139	139	99	1	------	3.6	78	78	100	------	------	3.6
						Chestnut						
Creosote	------	------	------	------	------	------	------	------	------	------	------	------
Card	164	164	18	82	------	10.1	89	89	9	91	------	10.2
Burnett	------	------	------	------	------	------	------	------	------	------	------	------
Untreated	169	169	28	72	------	9.4	90	90	22	78	------	10.2
						Cottonwood						
Creosote	88	46	6	47	31.0	25.2	45	17	16	22	34.5	24.1
Card	296	248	30	54	24.5	19.3	160	142	26	63	23.5	18.0
Burnett	------	------	------	------	------	------	------	------	------	------	------	------
Untreated	56	56	95	5	------	2.6	30	30	100	------	------	3.5
						Cypress						
Creosote	25	16	8	56	28.5	26.0	29	27	41	52	------	19.8
Card	409	358	11	76	24.0	19.5	254	232	25	66	------	18.4
Burnett	25	25	12	88	------	21.6	30	30	50	50	------	14.7
Untreated	135	134	78	21	------	8.8	90	90	89	11	------	7.5

1938 Inspection of Cross Tie Test Track, Chicago, Burlington & Quincy—Results of 29 Years of Service (Continued)

	Lines East						Lines West					
Process	Total placed	Total removed to date	Per cent removed account decay	Per cent removed account other causes	Estimated years average life	Actual years average life to date	Total placed	Total removed to date	Per cent removed account decay	Per cent removed account other causes	Estimated years average life	Actual years average life to date
						Elm						
Creosote	208	135	31	34	28.5	24.2	119	54	11	35	32.0	24.2
Card	594	475	29	51	25.5	20.9	371	301	30	52	25.0	20.5
Burnett	224	217	49	48	------	18.9	73	73	63	37	------	16.1
Untreated	113	113	91	9	------	4.8	78	78	96	4	------	5.9
						Hemlock						
Creosote	136	120	32	56	24.0	19.9	99	86	23	63	24.0	18.8
Card	816	767	29	65	------	18.2	488	471	39	56	------	15.9
Burnett	125	122	48	50	------	17.3	87	86	41	57	------	15.5
Untreated	112	112	100	------	------	4.7	78	78	99	1	------	5.3
						Hickory						
Creosote	10	7	10	60	27.5	24.7	15	12	13	67	25.5	21.4
Card	185	182	32	66	------	16.3	105	102	43	54	------	15.9
Burnett	9	8	22	67	24.0	21.6	15	15	53	47	------	17.3
Untreated	65	65	89	11	------	5.5	45	45	100	------	------	5.5
						Pine—Loblolly Sap						
Creosote	145	101	10	60	27.5	23.8	72	56	19	58	26.0	18.8
Card	949	812	30	56	24.5	19.4	386	366	26	68	------	15.7
Burnett	128	128	74	26	------	12.4	72	72	46	54	------	12.0
Untreated	157	157	99	1	------	5.5	91	91	100	------	------	4.8
						Hard Maple						
Creosote	82	61	49	26	26.5	24.2	34	23	18	50	28.0	22.8
Card	560	458	42	40	25.5	20.5	272	253	37	56	------	19.2
Burnett	50	49	50	48	------	19.6	15	15	87	13	------	16.7
Untreated	77	77	98	2	------	4.3	45	45	100	------	------	5.3
						Soft Maple						
Creosote	139	124	47	42	23.5	19.5	63	41	29	37	28.0	21.9
Card	462	425	50	42	------	17.2	264	235	31	58	23.5	18.8
Burnett	125	125	64	36	------	13.4	57	57	39	61	------	13.6
Untreated	82	82	99	1	------	3.4	43	43	95	5	------	4.0

White Oak												
Creosote	25	15	12	48	29.0	26.1	15	14	27	67	------	19.5
Card	234	231	39	60	------	17.2	152	148	31	66	------	17.1
Burnett	28	28	60	40	------	17.4	15	15	40	60	------	15.3
Untreated	81	81	88	12	------	10.8	44	44	81	19	------	11.7
Red Oak												
Creosote	165	96	5	53	29.5	24.8	120	92	13	63	26.0	22.5
Card	776	705	25	66	------	19.9	510	498	34	64	------	17.4
Burnett	158	157	56	44	------	17.2	116	115	47	52	------	15.3
Untreated	129	129	96	4	------	5.1	75	75	93	7	------	5.7
Pin Oak												
Creosote	189	96	6	44	31.0	25.6	133	80	10	50	29.0	24.6
Card	512	440	25	61	24.5	21.6	321	298	27	66	------	19.7
Burnett	23	21	57	35	------	22.5	44	44	32	68	------	16.0
Untreated	81	81	96	4	------	6.4	45	45	98	2	------	6.2
Poplar												
Creosote	50	37	18	56	26.5	23.7	30	27	17	73	23.5	17.2
Card	396	383	43	54	------	15.5	253	244	44	53	------	15.5
Burnett	50	50	44	56	------	14.3	30	30	57	43	------	13.0
Untreated	81	81	94	6	------	5.1	45	45	96	4	------	5.6
Red Gum												
Creosote	89	66	33	42	26.5	20.7	48	33	27	42	27.5	19.1
Card	429	368	42	44	24.0	19.4	233	184	44	35	25.0	19.9
Burnett	75	74	66	33	------	11.6	43	43	74	26	------	12.4
Untreated	98	98	97	3	------	3.8	54	54	98	2	------	4.6
Sycamore												
Creosote	75	46	37	24	29.0	24.0	15	4	------	27	38.0	26.1
Card	399	328	51	31	25.0	19.7	121	115	65	30	------	14.7
Burnett	75	75	71	29	------	13.7	15	15	80	20	------	13.5
Untreated	81	81	98	2	------	2.9	50	50	96	4	------	3.9
Tamarack												
Creosote	106	93	12	76	24.0	21.5	108	91	15	69	24.5	19.1
Card	813	794	22	76	------	18.1	494	464	33	61	------	17.7
Burnett	108	106	43	56	------	18.1	107	106	32	67	------	16.0
Untreated	98	98	96	4	------	4.9	77	77	99	1	------	5.3
Tupelo Gum												
Creosote	99	70	25	46	27.0	22.2	54	36	22	44	28.0	20.7
Card	436	300	22	47	27.5	23.0	237	129	27	28	31.0	24.5
Burnett	76	75	47	51	------	15.2	41	41	61	39	------	14.0
Untreated	88	88	98	2		3.0	48	48	98	2	------	4.4

Chicago, Indianapolis & Louisville—Experimental Track North of Lafayette Shops. Installed in 1914

Condition of Treated Ties May 22, 1939

Kind and markings	Original number installed	Absorption in lb.,		Total number of ties removed up to				Per cent of ties removed up to May, 1939	Remarks
		per tie	per cu. ft.	1923	1931	1935	1939		
White oak **W.O-1 to W.O-131**	131	22.6	8.3	0	63	69	131	100	Ties were removed on acct. lead to contractor's track in 1936.
Sawed red oak **R.O.-1 to R.O.-71** **R.O.-258 to R.O.-386**	200	20.6	7.7	0	8	13	127	64	Remaining ties in fair condition, 10 per cent should be replaced.
Hewn red oak **R.O.-72 to R.O.-257** **R.O.-387 to R.O.-400**	200	20.6	7.7	0	13	13	158	79	Remaining ties in fair condition, 10 per cent should be replaced.
Sawed beech **B-201 to B-400**	200	18.7	7.0	0	0	0	113	57	Remaining ties in fair condition, 10 per cent should be replaced.
Hewn beech **B-1 to B-200**	200	30.1	11.3	0	0	1	72	36	Remaining ties in fair condition, 10 per cent should be replaced.
Hewn pine **P-1 to P-200**	200	24.5	9.2	0	5	13	98	49	90 per cent of remaining ties should be replaced.
Hewn sassafras **S-11 to S-25**	15	9.4	3.1	0	8	8	14	94	Remaining tie in fair condition.
Hewn black walnut **S-1 to S-4**	4	12.4	4.6	0	0	0	0	0	Ties in good condition.
Hewn cherry **S-5 to S-10**	6	19.4	7.3	0	0	0	5	83	Remaining tie should be removed.
Hewn mulberry **S-26 to S-27**	2	3.5	1.3	0	0	0	1	50	Remaining tie in fair condition.
Elm, hewn and sawed **M-1 to M-201**	201	23.3	8.7	0	4	8	20	10	50 per cent of remaining ties should be replaced.

CHICAGO & EASTERN ILLINOIS

Test ties were placed in the northbound main track just south of Tuscola, Ill., at the time this second main track was constructed in the fall of 1912. A careful record was made of the place the ties were cut, length of seasoning and treatments given them. Each kind of tie is marked with a different kind of dating nail and any test tie renewed is replaced by a test tie marked with a nail showing the year tie was renewed.

The inspection of the test ties is made each year for the purpose of seeing that only ties requiring renewals are removed.

The following statement shows the number of ties that will have been removed to December 31, 1939 after a life of 27 years.

	Number Inserted	*Number Removed All Causes*	*Percent Removed All Causes*	*Aver. Life of Ties Removed in Years*
Untreated white oak	1,470	1,470	100.0	9.80
½ lb. zinc treated beech	803	803	100.0	13.42
½ lb. zinc treated gum tie plated	353	353	100.0	15.43
½ lb. zinc treated red oak	1,441	1,441	100.0	14.56
Aver. ½ lb. zinc treated ties	2,597	2,597	100.0	14.32
⅓ lb. zinc treated ties	1,345	1,345	100.0	12.64
Creosoted elm ties	1,356	697	51.4	24.22
Creosoted red oak	2,820	1,556	55.2	24.21
Creosoted beech	1,507	719	47.7	24.15
Total creosoted ties	5,683	2,972	52.2	24.20

GREAT NORTHERN SUMMARY STATEMENT—CREOSOTED WHITE BIRCH TEST TIES PLACED IN TRACK SPRING OF 1908

Division	*Number Originally Placed*	*Number Now in Service*	*Number Removed From all Causes*	*Percent Removed*	*Estimated Average Expected Life in Years*	*Average Life of Untreated Birch Years*
Main lines						
Ties 7″ x 7″—8′						
Mesabi	1,410	517	893	63.3	25	5
Willmar	986	528	458	46.5	29	5
Dakota	1,814	913	901	49.7	28	5
Minot	1,391	546	845	60.7	26	5
Butte	1,070	456	614	57.4	27	5
Total	6,671	2,960	3,711	55.6	27	5
Branch lines						
Ties 6″ x 7″—8′						
Mesabi						
(Princeton line)	1,419	521	898	63.3	25	5
(Park Rapids line)	1,447	916	531	36.7	30	5
Total	2,866	1,437	1,429	49.9	28	5
Grand Total	9,537	4,397	5,140	53.9	28	5

Note:—Ties were hewed—treatment 8 lb. per cu. ft. straight creosote. Ties treated green without air seasoning.

GREAT NORTHERN—CRESOIL-TREATED TEST TIES NEAR QUINCY, WASH.

SPECIES: Coast Douglas fir.
WHERE GROWN: Washington.
FORM: Square sawed.
DIMENSIONS: 7 in. by 9 in. by 8 ft.
WHERE SET: Starting 450 ft. E of MP 1613. 2½ miles east of Quincy, Wash., extending east about ½ mile.
DATE SET: March, 1924.
TRACK: Tangent—level grade.
NUMBER OF TIES SET: 498
SPACING IN TRACK: Twenty per 33-ft. rail.
PREPARATION: Ties were seasoned artificially in dry kilns for 6 days—Moisture content 20 percent.
PRESERVATIVE: Cresoil ties No. 1—No. 270—10 percent cresylic acid—90 percent petroleum oil.
PRESERVATIVE: Cresoil ties No. 271—No. 500—5 percent cresylic acid—95 percent petroleum oil.
PROCESS: Empty cell—Lowry.
ABSORPTION: Gross 20 lb. per cu. ft.—Net 6¾ lb. per cu. ft.
TIE PLATES: 7 in. by 10 in. by ½ in. Single Shoulder.
BALLAST: Very sandy gravel—Adrian pit.
WEIGHT OF RAIL: 100 lb.
SPIKES: Cut ⅝ in. by 6 in.
DATE INSPECTED: August 17, 1939.
NUMBER REMOVED PAST YEAR: 36.
NUMBER REMOVED TO DATE: 36.
AVERAGE LIFE TO DATE: 15 years.
EXPECTED AVERAGE LIFE: 20 years.
PRESENT CONDITION: Fair. A number of the ties are badly plate cut and splitting.
REMARKS: All ties are marked with a 1½ in. by 3 in. copper number plate. Ties No. 141 and No. 211 left out of track account being split.

GREAT NORTHERN SERVICE RECORD OF TEST TIES

LOCATION: Double track—Stone Arch bridge—Minneapolis, Minn.
NUMBER OF TIES IN TEST: 1269 on e. b. and 1047 on w. b. track—

EB	729 Hewed 540 Square sawed	WB	800 Hewed 469 Square sawed

DATE SET: October, 1924.
SPECIES: Minnesota white birch.
DIMENSIONS: 7 in. by 9 in. by 8 ft.
SPACING IN TRACK: 20 per 33-ft. rail.
PREPARATION: Air seasoned, adzed and bored.
PRESERVATIVE: 50–50 creosote and petroleum.
PROCESS: Lowry.
ABSORPTION: 8 lb. per cu. ft.
TIE PLATES: Single shoulder 7 in. by 10 in. by ½ in.
BALLAST: Washed gravel.
RAIL: Weight 100 lb.
SPIKES: Cut ⅝ in. by 6 in.
IDENTIFICATION: 1924 dating nail.
TRAFFIC: 32 scheduled passenger trains daily on each track. No freights.
DATE INSPECTED: August 7, 1939.
NUMBER REMOVED THIS PERIOD: None. Percent: None.
NUMBER REMOVED TO DATE: None. Percent: None.
CAUSE OF REMOVAL THIS PERIOD: None. Percent: None.
PRESENT CONDITION: Good. Some are checked.
DATE OF THIS REPORT: August 8, 1939.
REMARKS: 222 Tamarack ties eliminated from test.

GREAT NORTHERN—RECORD OF TEST TIES BETWEEN GERBER AND BELT, MONT.—BUTTE DIVISION

(Ties Treated During 1910—Track Laid Spring of 1911)

Kind of ties	Number of ties originally placed	Number now in service	Number removed from all causes	Per cent removed to date	Average life to 4-1-39
Untreated ties—various types and species					
					Years actual
Pine—sawed triangular	2,010	None	2,010	100	8.0
Pine—slabbed	1,145	None	1,145	100	6.7
Larch—sawed triangular	1,836	None	1,836	100	6.7
Larch—sawed square	1,277	None	1,277	100	7.5
Larch—slabbed	1,236	None	1,236	100	7.6
Fir—sawed triangular	1,978	None	1,978	100	7.7
Fir—slabbed	1,340	None	1,340	100	7.8
Total	10,822	None	10,822	100	7.5
4 per cent zinc chloride treatment ½ lb. per cu. ft.					Years
Pine—sawed triangular	1,974	21	1,953	98.94	15.7
Pine—sawed square	1,327	5	1,322	99.62	14.5
Pine—slabbed	3,328	15	3,313	99.55	14.7
Larch—sawed triangular	1,887	37	1,850	98.04	16.5
Larch—sawed square	1,318	38	1,280	97.12	17.0
Larch—slabbed	1,273	50	1,223	96.07	17.5
Fir—sawed triangular	1,635	22	1,613	98.65	17.0
Fir—sawed square	928	10	918	98.92	16.9
Fir—slabbed	1,286	33	1,253	97.43	16.7
Total	14,956	231	14,725	98.46	16.0
6 per cent zinc chloride treatment ¾ lb. per cu. ft.					Years
Pine—sawed triangular	2,004	95	1,909	95.26	17.7
Pine—sawed square	1,367	28	1,339	97.95	16.7
Larch—sawed triangular	2,084	112	1,972	94.63	18.1
Larch—slabbed	1,433	55	1,378	96.16	17.5
Fir—sawed triangular	1,988	13	1,975	99.35	15.5
Fir—sawed square	819	4	815	99.51	15.0
Fir—slabbed	1,274	18	1,256	98.59	16.0
Total	10,969	325	10,644	97.04	16.5
		Summary			
					Years actual
Untreated pine	3,155	None	3,155	100	7.4
Untreated larch	4,349	None	4,349	100	7.3
Untreated fir	3,318	None	3,318	100	7.8
Total	10,822	None	10,822	100	7.5
					Years
4 per cent zinc chloride—					
pine	6,629	41	6,588	99.37	15.0
larch	4,478	125	4,353	97.08	17.0
fir	3,849	65	3,784	98.33	16.2
Total	14,956	231	14,725	98.46	16.0
					Years
6 per cent zinc chloride—					
pine	3,371	123	3,248	96.60	16.7
larch	3,517	167	3,350	95.40	17.3
fir	4,081	35	4,046	99.15	15.0
Total	10,969	325	10,644	97.04	16.5

REMARKS: All test ties were laid out of face. Dating nails applied in end of tie, showing year and species of wood, and whether untreated, 3 per cent zinc chloride or 4 per cent zinc chloride.

NORTHERN PACIFIC—HEMLOCK TEST TRACK

Designated by U. S. Forest Service as Project L–214.

1800 Montana–Idaho hewed and sawed ties placed between mile post 120 and mile post 121–2350, westward main track, Missoula, Mont.

Treated at Paradise, Mont., with 80–20 creosote-coal tar solution, 6¾ lb. per cu. ft. Lowry process, and placed in track in 1910.

SUMMARY OF TIES BY SPECIES

Year	*Western Hemlock*	*Western Larch*	*Douglas Fir*	*True Fir*	*Spruce*	*White Pine*	*Ponderosa Pine*	*Aspen*	*Total*
1910	1,072	436	166	102	18	2	3	1	1,800
			Renewals						
Year									
1917	1	....	....	....	....	....	....	....	1
1924	1	....	....	....	....	....	....	....	1
1926	4	....	....	....	....	....	....	....	4
1928	43	....	....	....	....	....	....	....	43
1929	26	8	6	14	5	....	....	....	59
1932	49	9	....	....	3	....	....	....	61
1933	28	8	4	1	1	....	....	....	42
1934	43	18	1	6	....	....	....	....	68
1935	29	9	5	4	....	....	....	....	47
1936	42	11	3	1	....	....	1	....	58
1937	78	24	4	5	4	....	....	....	115
1938	72	24	1	6	....	....	....	....	103
1939	42	16	3	4	1	....	....	....	66
Total	458	127	27	41	14	0	1	0	668
Percent renewed	42.72	29.13	16.27	40.20	77.78	0	33.33	0	37.11
Avg. yrs. per tie	24.59	25.68	24.30	23.85	22.93	0	26.00	0	24.71

Six ties removed prior to 1928 were broken by derailment. Others all removed account decay hastened by damage from past derailments and mechanical attrition at rail base.

37.11 percent renewals in 29 years.

Average life of ties replaced—24.71 years.

Estimated total life based on Tie-Life Curve of the United States Forest Products Laboratory—34 years.

NORTHERN PACIFIC—TAMARACK TEST TRACK

44,159 Hewed Minnesota tamarack ties placed between mile posts 88 and 103½, in eastward main track, Rice, Minn. to Gregory.

Treated at Brainerd, Minn. with 80–20 creosote-coal tar solution, 6¾ lb. per cu. ft.—Lowry process and placed in track in 1917.

Renewals

None previous to 1928.
1928...... 1 tie account decay. Showed signs of having been partially decayed when treated.
1929...... 239 ties account derailment.
1930...... No renewals.
1931...... 3 ties account decay.
1932...... No renewals.
1933...... No renewals.
1934...... No renewals.
1935...... 214 decay at rail base caused by mechanical wear.
1936...... 1,785 decay at rail base caused by mechanical wear.
1937...... 3,002 decay at rail base caused by mechanical wear.
1938...... 3,454 decay at rail base caused by mechanical wear.
1939...... 2,448 decay at rail base caused by mechanical wear.

11,146 Ties renewed, 25.2 percent after 22 years.

Average life of ties removed—20.38 years.

Estimated total life based on Tie-Life Curve of the United States Forest Products Laboratory—28 years.

NORTHERN PACIFIC—COTTONWOOD TEST TRACK

261 Hewed and sawed western Montana cottonwood ties placed near mile post 12, Bitter Root branch, near Missoula, Mont.

Treated at Paradise, Mont. with 80–20 creosote-coal tar solution, 8 lb. per cu. ft., Lowry process, and placed in track in 1910.

Renewals

None previous to 1923.
1923...... 1 broken.
1925...... 2 split and crushed.
1927...... 3 rail cut and decayed.
1928...... No renewals.
1929...... 24 rail cut and decayed.
1930...... 2 burned by weed burner.
1931...... No renewals.
1932...... 3 rail cut and decayed.
1933...... No renewals.
1934...... No renewals.
1935...... No renewals.
1936...... 16 crushed and decayed at rail base.
1937...... No renewals.
1938...... No renewals.
1939...... No renewals.

51 ties renewed, 19.5 percent after 29 years.

Average life of ties removed—21.02 years.

Estimated total life based on Tie-Life Curve of the United States Forest Products Laboratory—38 Years.

UNION PACIFIC—1938 INSPECTION—HAMMETT—REVERSE TEST SECTION

Designation	Kind	Treatment	Date put in	Number put in	Number removed	Cause	Approx. years service	Per cent in track	Condition
A	Sawed western yellow pine, air seasoned	80% creosote 20% coal tar, 10 lb. Bethell process	12–23	64	------	----------------	15	100	Excellent
B	Hewed lodgepole pine, air seasoned	80% creosote 20% coal tar, 10 lb. Bethell process	12–23	170	------	----------------	15	100	Excellent
C	Sawed coast fir, air seasoned	0.5 lb. zinc chloride Burnett process	12–23	950	178	Rotten and checked	15	81	Badly checked, considerable plate cutting and rotten on under side.
D	Hewed lodgepole pine air seasoned	0.5 lb. zinc chloride Burnett process	12–23	626	240	Plate cut, rotten and checked	15	62	Checking and plate cutting
E	Hewed Idaho red fir and tamarack, air seasoned	0.5 lb. zinc chloride Burnett process	12–23	452	240	Rotten and checked	15	47	Checking and plate cutting progressive rotting on under side.
F	Sawed western yellow pine, air seasoned	0.5 lb. zinc chloride Burnett process	1–24	757	55	Rotten	14	93	Considerable checking rail cutting and rotting on under side.
G	Hewed lodgepole pine, air seasoned	30% creosote 7½% coal tar 62½% fuel oil 10 lb. Bethell process	11–23	625	------	----------------	15	100	Very good, slightly plate cutting on out side of rail on inside of curve.
H	Sawed coast fir, air seasoned	30% creosote 7½% coal tar 62½% fuel oil 10 lb. Bethell process	12–23	766	------	----------------	15	100	Very good, slightly plate cut on out side of rail on inside at curve.
I	Hewed Idaho red fir and tamarack, air seasoned	30% creosote 7½% coal tar 62½% fuel oil 10 lb. Bethell process	12–23	633	------	----------------	15	100	Very good, slightly plate cut on out side of rail on inside of curve.
J	Sawed white fir and spruce, air seasoned	0.5 lb. zinc chloride Burnett process	12–23	782	782	Checked, shattered and rotten	15	0	(All have been replaced)
K	Sawed western yellow pine air seasoned	30% creosote 7½% coal tar 62½% fuel oil 10 lb. Bethell process	12–23	741	------	----------------	15	100	Excellent, one broken account large knot.
L	Sawed white fir and spruce, air seasoned	30% creosote 7½% coal tar 62½% fuel oil 10 lb. Bethell process	12–23	720	10	Rotten	15	99	Very good

UNION PACIFIC—1938 INSPECTION—ORCHARD–BOISE—MAIN LINE TEST SECTION

Designation	Kind	Treatment	Date put in	Number put in	Number removed	Cause	Approx. years service	Per cent in track	Condition
A	Sawed coast fir, air seasoned	4 lb. creosote 4 lb. fuel oil Lowry process	5–24	780	5	Checked	14	99	Very good—some checking
B	Sawed white fir, air seasoned	3.6 lb. creosote 8.4 lb. fuel oil Lowry process	5–24	782	8	Rail cut and checked	14	99	Very good, slightly rail cut at joints, some checking
C	Sawed western yellow pine, air seasoned	0.5 lb. zinc chloride Burnett process	3–24	3,069	451	Rotten, checked, broken	14	85	Fair, progressive checking & plate cutting, some rotten on under side.
D	Sawed white fir and spruce, air seasoned	8.6 lb. creosote 0.4 lb. fuel oil Lowry process	3–24	3,131	------	----------------	14	100	Very good, slightly cut at joints.
E	Sawed white fir and spruce, air seasoned	0.5 lb. zinc chloride Burnett process	4–24	2,915	781	Rotten, checked, shattered	14	73	Rotten on under side considerable checkin and rail cutting.
F	Sawed Idaho red fir, air seasoned	8 lb. creosote Lowry process	4–24	3,081	------	----------------	14	100	Excellent
G	Sawed lodgepole pine, air seasoned	8 lb. creosote Lowry process	5.24	776	------	----------------	14	100	Excellent
H	Sawed western yellow pine, air seasoned	8 lb. creosote Lowry process	5–24	2,579	------	----------------	14	100	Excellent
I	Sawed coast fir, air seasoned	8 lb. creosote Lowry process	5–24	3,078	------	----------------	14	100	Excellent, 42 ties east end damaged by dragging equipment.
J	Hewed lodgepole pine, air seasoned	8 lb. creosote Lowry process	5–24	2,555	------	----------------	14	100	Excellent
K	Hewed lodgepole pine, air seasoned	0.5 lb. zinc chloride Burnett process	5–24	2,374	501	Rotten, checked, shattered	14	79	Progressive checking and plate cutting rot in sapwood to extent of 1½ in. to 2 in. deep.
L	Sawed lodgepole pine, air seasoned	0.40 lb. zinc chloride Burnett process	6–24	767	207	Rotten, checked, shattered	14	73	Progressive checking, rotten on under side.
M	Sawed Idaho red fir, air seasoned	0.5 lb. zinc chloride Burnett process	6–24	3,143	699	Rotten, checked, shattered	14	78	Progressive checking and plate cutting rotten on under side.
N	Sawed coast fir, air seasoned	0.418 lb. zinc chloride Burnett process	6–24	3,037	348	Rotten, checked, shattered	14	88	Progress plate cutting, badly checked and shattered, rotten on under side.

UNION PACIFIC RAILROAD COMPANY—1938 INSPECTION—DIETRICH TO SHOSHONE—MAIN LINE TEST SECTION

Designation	Kind	Treatment	Date put in	Number put in	Number removed	Cause	Approx. years service	Per cent in track	Condition
A	Hewed lodgepole pine, air seasoned	0.4 lb. zinc chloride Burnett process	1–27	780	286	Shattered	11	63	Fair, checking, splitting and plate cutting.
2	Hewn lodgepole pine, air seasoned	0.5 lb. zinc chloride 6 mo. seasoning 7.909 lb. fuel oil	1–27	799	------	----------------	11	100	Good, slight plate cutting at joints and few checking.

Union Pacific—1938 Inspection—Wells Branch Test Station

Designation	Kind	Treatment	Date put in	Number put in	Number removed	Cause	Approx. years service	Per cent in track	Condition
1	Sawed white fir and spruce	0.5 lb. zinc chloride Burnett process	12–24	3,197	1,797	Rotten	14	44	Very bad rotting fast.
2	Sawed west coast fir, air seasoned	8.0 lb. creosote Bethell process	8–24	3,148	------	----------------	14	100	Excellent
3	Sawed west coast fir, air seasoned	0.5 lb. zinc chloride Burnett process	9–24	3,210	911	Rotten, checking	14	71	Bad checking and considerable rot under side.
4	Sawed west coast fir, air seasoned	0.5 lb. zinc chloride 3½ lb. fuel oil Two movement	12–24	3,171	281	Rotten, checking	14	91	Very good except some checking and rot
5	Sawed western yellow pine, air seasoned	0.5 lb. zinc chloride Burnett process	12–24	3,186	231	Checking, burned, broken and rotten	14	93	Fair, progressive checking and rot
6	Sawed western yellow pine, air seasoned	0.5 lb. zinc chloride 3½ lb. fuel oil Two movement	1–25	3,142	------	----------------	13	100	Excellent
7	Sawed Idaho red fir, air seasoned	0.5 lb. zinc chloride Burnett process	7–8 1924	3,150	909	Rotten, checking	14	71	Fair, progressive checking and rail cutting. Some rotting on under side.
8	Sawed Idaho red fir, air seasoned	0.5 lb. zinc chloride 3½ lb. fuel oil Two movement	1–25	3,209	669	Rotten, checking	13	79	Fair, some checking and rail cutting and rotting on under side.
9	Hewed lodgepole pine, air seasoned	0.5 lb. zinc chloride Burnett process	9–24	2,538	531	Rotten & checking	14	79	Progressive checking rail cutting and rotting on under side.
10	Hewed lodgepole pine, air seasoned	0.5 lb. zinc chloride 3½ lb. fuel oil Two movement	2–25	2,297	------	----------------	13	100	Very good
11	Sawed lodgepole pine, air seasoned	0.5 lb. zinc chloride Burnett process	1–25	3,173	521	Rotten and checking	13	84	Fair, checking, rail cutting and some rotting on under side.
12	Sawed white fir and spruce, air seasoned	0.5 lb. zinc chloride 3½ lb. fuel oil Two movement	12–24	3,166	198	Rotten	14	94	Rail cut and rotting.
13	Hewed Idaho red fir, air seasoned	0.5 lb. zinc chloride 3½ lb. fuel oil Two movement	12–24	2,526	84	Rotten	14	97	Good, slightly checking and plate cutting and rotting.
14	Hewed Idaho red fir, air seasoned	0.5 lb. zinc chloride Burnett process	1–25	2,562	740	Rotten and checking badly	13	71	Poor, checking and rail cutting sap rot and rotting on under side.

St. Rosalie Junction, Que. CANADIAN NATIONAL

Sawn beech, birch and maple ties. Treated at Trenton, Ont., 8 lb. 80–20 mixture Lowry process, 1915.

Year inserted: 1915
Original number inserted: 863
Total removed to January 1, 1939: 311
Percentage removed: 36.3
Expected average life: 27 years

St. Clet, Que. CANADIAN PACIFIC

Air seasoned incised jack pine, treatment 9.3 lb. 100 percent creosote, Lowry process, 1919.

Year inserted: 1919
Original number inserted: 40
Total removed: Nil
Percentage removed: Nil
Expected average life: ..

St. Clet, Que.

Air seasoned jack pine not incised, treatment 11.2 lb. 100 percent creosote, Lowry process, 1919.

Year inserted: 1919
Original number inserted: 40
Total removed: Nil
Percentage removed: Nil
Expected average life: ..

St. Clet, Que.

Air seasoned incised hemlock ties, treatment 7.2 lb. 100 percent creosote, Lowry process, 1919.

Year inserted: 1919
Original number inserted: 79
Total removed: Nil
Percentage removed: Nil
Expected average life: ..

Virden, Man.

Mixed jack pine, spruce, poplar and tamarack ties, treated at Sommerville, Tex., 1906, with 4¾ lb. German creosote, Rueping process.

Year inserted: 1906
Original number inserted: 150
Number removed to January 1, 1939: 73
Percentage removed: 49
Expected average life: 34 years

Rugby Jct., Man.

Spruce ties treated at Minneapolis, Minn., 1909. No record of preservative, absorption or process.

Year inserted: 1909
Original number inserted: 240
Number removed to January 1, 1939: 134
Percentage removed: 56
Expected average life: 30 years

Appendix B

(3) Piles Used for Marine Construction

Wm. G. Atwood (chairman, subcommittee), C. S. Burt, W. F. Clapp, E. A. Craft, John Foley, H. E. Horrocks, A. L. Kammerer, A. M. Knowles, F. B. Robins, Dr. H. von Schrenk.

The committee submits a report of the inspections of the test pieces under its supervision together with such other information as it has been able to gather regarding the marine borer problem.

Turpentine Wood

The specimens at the Panama canal show little change from last year except that the attack of the pholads has progressed further.

The report of the Southern Pacific Company on the condition of the piles driven in the Oakland pier was not received in time for publication last year. These piles show no attack by teredine borers but some of them have been attacked by limnoria. The report of this year shows that these borers have made some progress in their attack in the past year but that it is not at all serious. It is stated that the attack is confined to the sapwood.

Panama Canal

The reports of Mr. James Zetek have been furnished by Brigadier General C. S. Ridley, governor of the Canal Zone and are abstracted below:

> The results this year are especially interesting in that the highly resistant timbers show no marked changes since last year. Teredo is not important, and in only a few cases the gribble (*Limnoria lignorum* Rathke) could be considered very active. In no case was the gribble as destructive as it is in other regions.
>
> The really destructive forms were the two pholad mollusks *Martesia Striata* Linne., and Hiata infelix Zetek and McLean, in some cases these were very abundant. Both are confined to the surfaces, but because of their size and shape, the cavities they make, and in which they live, extend in at least one inch. With the exception of these two pholads, and the relatively light gribble attack, these timbers are very sound. Most of these have been in these tests nearly sixteen years.
>
> Neither Sphaeroma nor Chelura were found.
>
> As regards the treated timbers, the creosoted Amorillo (1630–30) is of no further value as a test. The four-inch section cut from the end had over 100 teredo holes, confined to about half the section, roughly 75 sq. in. These teredo holes were mostly from ½ to ⅜ in. in diameter. It seems that these teredo are confined to the part of the timber that shows less penetration.
>
> As to the Chemonite treated timbers, both give a clean appearance, but the presence of many pin holes is very suggestive of teredo. No pholads were seen, nor was any gribble attack in evidence. * * * Present indications are that this treatment will not hold up against teredo. It seems to ward off limnoria. The absence of the two pholads can have no meaning as yet since the timbers have been in test only two years and five months.

A—Untreated Timbers

> 1609–2 Anoura, *Conepia sp.,* Dutch Guiana, submerged September 13, 1923. Marine growth was scant and the 1937 cut face is practically free from such growth. Gribble damage is at least ½ in. deep, but there is none so far on the 1937 cut face. The pholads Martesia and Hiata are present in fair number and cause most of the damage, confined to the surfaces but no signs of any on the cut face. Teredos are small, not numerous, and confined close to the surfaces. Except for the gribble and pholads, the timber is very sound.

1612–3 Basra Locus (Angelique) *Dicorynia paraensis* Bentham, Dutch Guiana, submerged September 9, 1923. Marine growth not abundant, only a few oysters on the 1937 cut face. Gribble damage less than on Anoura, not yet on the cut face. The two pholads rather plentiful, some already starting on the cut face. Teredos are all small and close to the surfaces, more plentiful than in Anoura. Except for surface damage, the timber is very sound.

1608–4 Foengo, *Paranarium campestre* Aubl., Dutch Guiana, submerged September 13, 1923. Marine growth abundant, less so on 1937 cut face. Gribble damage about as in Anoura and already starting on the cut face. Both pholads are plentiful and already starting on the cut face. Teredos are not plentiful, are all small, and confined to the surfaces. Except for this surface damage the timber is sound.

1610–5 Sponse Hoedoe, *Licania macrophylla* Bentham, Dutch Guiana, submerged September 13, 1923. Marine growth was plentiful, even on the 1937 cut surface. Gribble damage about as in Basra Locus and there is some invasion on the cut face. Both pholads are abundant, also invading the cut face, and these are responsible for practically all of the surface damage. Teredos are small and close to the surfaces, not plentiful. Timber otherwise sound.

1613–7 Manbarklak, *Eschwilers longipes* Miers., Dutch Guiana, submerged September 13, 1923. Marine growth plentiful, less so on the 1937 cut face. Gribble damage very moderate. The two pholads are fairly abundant and cause most of the surface destruction. Only one face shows decided gribble attack. Teredos are not plentiful, mostly small and close to the surfaces. Otherwise the timber is very sound.

1609–9 Malabayabas, *Tristania decoritata* Merr., Philippine Islands, submerged September 13, 1923. Marine growth very plentiful, and 1937 cut face covered with oysters. Considerable silt. Gribble damage was light except on one face which shows considerable attack, not deep however. Both pholads are abundant and have started to invade the cut face. Teredos are small, apparently few in number and close to the surfaces. Except for pholad destruction the timber is very sound.

1615–11 Kajol Lara, *Metrosideros sp.*, Celebes, submerged October 26, 1925. Marine growth abundant. Gribble work very light. Both pholads present but not abundant. Teredos are few in number, all small and close to the surfaces. Timber very sound.

1616–12 Kajol Malas, Parastemon urophyllum, Sumatra, submerged October 26, 1925. Marine growth not pronounced. Gribble work light, but more than in Kajol Lara. Both pholads present but few in number. Teredos are apparently few in number, small and close to the surfaces. Timber sound.

1637–13 Kolaka, Celebes, submerged April 15, 1932. Marine growth very abundant, some silt present. Gribble work is very light, almost nil. Teredos are very few, small and close to the surfaces. The two pholads are likewise few in number. Timber very sound.

1617–14 Alcornoque, *Dimorphandra mora* B. & H., Panama all heartwood, submerged September 22, 1927. Marine growth fairly plentiful. Gribble work was very light. Teredos do not seem to be plentiful, are small and confined to the surfaces. Both pholads are present but not abundant. Timber sound.

1625–22 Brush-box, New South Wales, submerged April 19, 1929. Except for oysters which are abundant, marine growth scant. Much silt. Gribble work almost nil except on one face which showed more attack but not deep. Both pholads few in number. Teredos seem to be few in number, all small and confined to surfaces. Timber sound.

B—Treated Timbers

1630–30 Creosoted Amorillo, *Chlorophora tinctorea*, Panama, treated with No. 1 coal tar creosote, one end scarfed after treatment, submerged September 20, 1930. Great amount of marine growth. Much silt. More teredo holes in the cut end. Both pholads plentiful. We cut off a section four inches thick. The best description possible is the photograph made of the cut surface. Over 100 teredo holes are present, the largest ⅜ in. in diameter, all confined to an area 6 in. wide by 13 in., and this appears to be the part of the timber where the penetration was light. The other half is clean of teredos. (Fig. 1). This timber was very difficult to treat. It was dry when treated and was subjected to light pressure for over 24 hours. After this inspection the specimen was removed from test and cut into short sections for inspection. There was practically no attack in the treated section of the timber.

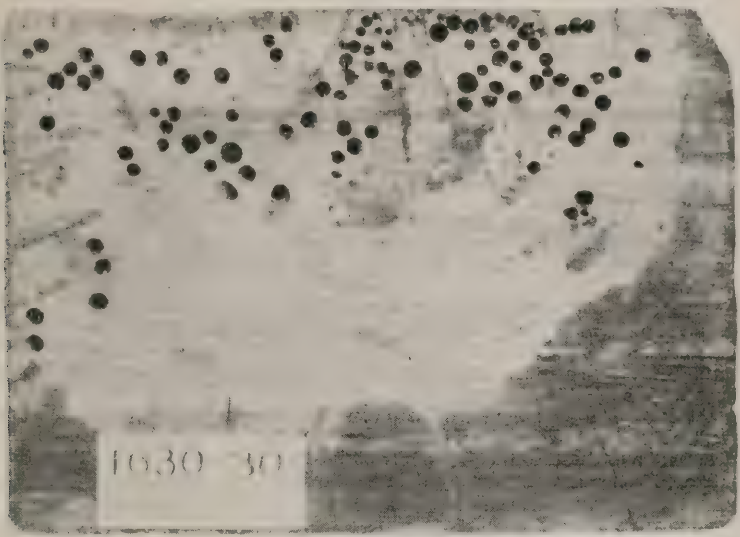

Fig. 1.—Specimen of Creosoted Amorillo Submerged at Panama in 1930, Damage Confined to Area Where Penetration Was Light.

1721–31 Chemonite treatment, southern yellow pine, 6 in. in diameter and 7 ft. long, submerged March 12, 1937.

There being two test pieces with this treatment, one of them was removed from test and cut into small sections for inspection. The number of teredo holes varied in the 15 different sections from none to 38.

Chemical Warfare Service Specimens

Series No. 1

No. 1—1 percent ammoniacal copper carbonate. The remaining test pieces at San Juan and in San Francisco bay show no change since last year. The intensity of borer attack is much less in these locations than it was 14 years ago, when the tests were submerged. The pieces at Castle Pinckney in the harbor of Charleston, S. C. are 90 percent destroyed.

No. 2—1 percent diphenylamine in creosote. The pieces at San Juan and in San Francisco bay show no change. Those at Castle Pinckney are 90 percent destroyed.

No. 3—0.75 percent diphenylamine in fuel oil are all practically destroyed and will not be reported in later reports.

Series No. 2

This series was treated at Edgewood Arsenal in 1931. The control pieces were treated with AREA No. 1 creosote and there were ten other series treated, five with creosote as a carrier and five with fuel oil. The chemicals used were methyl arsenious oxide, diphenylamine chlorarsene, and dinitrophenol in varying proportions. The end penetration was very poor and a large part of the destruction that has occurred has been caused by the entrance of borers into the ends of the pieces.

Two sets of these pieces were placed by the Corps of Engineers U.S.A. at Fort Tilden, N. Y. and Castle Pinckney in Charleston harbor, S. C., by the Bureau of Lighthouses at San Juan, P. R., by the Panama Canal Zone authorities at Miraflores, C. Z., by the Bureau of Yards and Docks, U. S. N. at the naval air station at Pensacola, Fla., the Puget Sound navy yard at Bremerton, Wash., The Pearl Harbor navy yard at Pearl Harbor, T. H., and the Cavite naval station at Cavite, P. I., also by the Southern Pacific Company in San Francisco bay. These tests have been discontinued at Miraflores, Puget Sound navy yard and at the Cavite naval station because of heavy attack through the ends of the pieces and at Cavite, also, because of the heavy attack by pholads.

At Fort Tilden, at the ocean entrance to New York harbor, the pieces on the west side of the narrow pier have not been so heavily attacked as those on the eastern side. The untreated control on the east side was practically destroyed by teredo and limnoria while the one on the west side was less heavily attacked. The treated pieces have all been more or less attacked, those with the fuel oil carrier much more heavily than those for which creosote was used.

At Castle Pinckney the pieces treated with straight creosote and creosote with methyl arsenious oxide are estimated to be 60 percent destroyed and the others with a creosote carrier 45 percent. Those in which a fuel oil carrier were used were destroyed several years ago.

No report has been received from the naval air station at Pensacola.

At the Southern Pacific Oakland pier, the remaining pieces, one treated with straight creosote and the other with creosote and dinitrophenol show a very light limnoria attack while two others with fuel oil carrier show heavy attack by limnoria and teredo.

At the Pearl Harbor navy yard the pieces treated with fuel oil carrier are practically destroyed, only a few fragments remain. Those treated with a creosote carrier have all been attacked but those containing dinitrophenol are somewhat better than the others. The untreated controls were destroyed in a year.

San Francisco Bay Tests

Barret Manufacturing Company Material

Thirty test pieces treated with creosotes manufactured by two processes, each of varying composition were submerged by the Southern Pacific Company in 1925. They are now at the Oakland pier. The untreated controls show practically no attack since the 1938 inspection, having lost only 0.25 percent and 0.1 percent in weight, respectively. There is no additional attack reported on any of the treated pieces except light limnoria attack on one coke oven oil minus fraction 270–360 and two vertical retort oils minus residue above 360 deg. C.

Long Wharf Piles

These piles, originally driven in 1890 and now at San Diego show no change except a limnoria attack on one of them around and under a copper patch placed over a point of limnoria attack in 1927. Two of these piles now at Long Beach are heavily attacked by limnoria, one being 25 percent and the other 75 percent destroyed. All others are in good condition. Several of these piles were lost because of an accident which damaged the pier in which they were.

New England Report

The investigation commenced in 1934 is still in progress under the direction of the New England Marine Piling committee.

About 200 test boards are being operated in the harbors of Newfoundland, Nova Scotia, Nw Brunswick, Maine, New Hampshire, Massachusetts, Rhode Island and in some of the Connecticut locations. The State of Connecticut has, it is hoped only temporarily discontinued the boards operated by it. The boards still operating in Connecticut show an increasing severity of attack by teredo and chelura.

The Newport testing station, which was practically destroyed by the hurricane of September, 1938, has been reestablished and is now in better condition than before the destruction. This station has under test a large number of tropical timbers, specimens treated with proprietary compounds, and various creosotes and creosote coal tar solutions. The test pieces were anchored to pipes above and concrete anchors before the storm but now have creosoted timber above and the suspension and anchor cables form a corrosion test of ten of the corrosion resisting metals. This testing station is being cared for by the local organization of the navy.

In 1939 the chelura have continued to be active in all of the harbors where they have appeared since 1934. In several, most notably, in Newport, R. I., they have greatly increased in numbers and the destruction is comparatively larger. The limnoria count on the timber has been correspondingly decreased. This is probably due to the fact that the chelura generally begins its activity in wood by occupying the limnoria burrows. Being larger and much more active in movement than the limnoria, many of the latter are driven from their burrows. The theory that chelura attack can not occur unless the timber shall have first been occupied by limnoria has been disproven. A number of timbers have been found under attack by chelura where there is no evidence that limnoria preceded them. This attack has always been found to have started where two timbers were in contact and where the space between them gave some protection. No attack has been found by chelura in well creosoted timber and it appears probable that this treatment gives immunity. All joints must be well protected from giving access to untreated wood.

A number of timbers treated with proprietary products have been attacked at Newport and at the tropical testing stations. The Chemonite and Palen treatments are being continued (see Panama Canal Report for Chemonite) as are tests of the tropical timbers.

In comparison between the two New England investigations, that of 1922–24 and the present one, it is very evident that the intensity of attack and the rate of destruction is much greater now than 15 years ago. It is also evident that the attack was more intense in 1939 than in 1934–35.

In a few cases changes in local conditions can be shown to be responsible for the increase but generally there is no apparent cause for the change. The theory of climatic change has many advocates, and considerable evidence has accumulated to support this theory, particularly when such changes are considered in cycles. It has been believed that these cycles of climatic changes, when sufficiently great to effect a fauna or flora, were to be measured by centuries rather than years.

It is therefore of interest to record, that in connection with the New England research it has been discovered that *Bankia gouldi,* a very destructive marine borer not now found north of New Jersey, was at some time plentiful, thriving and destructive in Boston harbor. Excavations made during the past summer in the filled land of what is now Back Bay, exposed over a large area a great number of small posts, sharpened at one end. The purpose of these posts is not known but they were planted there by man. Many were found to have been riddled by *Bankia gouldi.* No trace of *Teredo navalis,* the teredine borer now present in Boston, has been found. The deposit around the posts contains many shells which have been identified as belonging to species not now existing north of Cape Cod.

It is known that there has been a great extension northward of the destructive range of *Teredo navalis* during the past few years. Many other organisms are also known to have extended their range northward. These observations, together with those which have been made regarding *Bankia gouldi,* indicate that these waves of expansion or contraction of species' habitat may be measured in years. There is, therefore, additional evidence that the very destructive *Bankia gouldi* may be working north from its past northern boundary in New Jersey into the waters of Long Island sound or even further.

New York Investigation

At the present time there are 33 test boards down in New York harbor (plus 3 in the Baltimore district which are at present under the supervision of this committee), the first of which was submerged in March 1938. Some have been submerged for only three months.

The committee has representatives from railroads, pier owners and municipal and interstate bodies. They meet quarterly to discuss findings from test boards and water analyses. The water analyses are being made by the Interstate Sanitation Commission and samples are taken at all stages of the tide in the vicinity of the location of the test boards.

While the majority of the boards have not been down long enough to indicate any decisive trends which the committee would desire to make public, there has been enough evidence of marine borer attack in certain sections to convince the members of the committee of the desirability of continuing the work as a "fire alarm" against destructive attacks that may be in the making. As anticipated the greatest borer activity has been found at the ocean entrance to the harbor and the Long Island Sound approach, but some borers have also appeared at other points. The condition of the test blocks is being carefully checked against the local water samples to verify water conditions favorable to the multiplication of marine borers.

The chairman of this Subcommittee has just been informed of an extremely heavy attack at Fire Island Inlet on the south shore of Long Island. Teredo were plentiful there in 1922–24 but not more so than in some other places. A contract was recently let by the U. S. Engineers for the construction of a long stone groin or breakwater. The contractor drove a trestle for distributing the rock using large spruce piles. Two months after this trestle was finished and a locomotive crane was working from it the whole structure failed. The piles were cut off by teredo, which were so crowded in the timber that they were very small.

This report is offered as information and it is recommended that the subject be continued.

Appendix C

(5) Destruction by Termites and Possible Ways of Prevention

Dr. H. von Schrenk (chairman, subcommittee), Wm. G. Atwood, E. A. Craft, Dr. Wm. F. Clapp, John Foley, A. M. Knowles, F. D. Mattos, F. B. Robins, W. A. Summerhays.

In the Proceedings, Vol. 40, 1939, this subcommittee on page 505 gave a general statement of a second series of posts to be driven at Florissant, Mo., consisting of various soil poisons as well as pressure-treated pieces. This year the committee is simply making a progress report with reference to this test.

On May 11, 1939, 344 pieces of southern pine two-by-four sticks, each 2 feet long, were driven into the ground at Florissant. In this test a different method of distribution for the various kinds of treatment was adopted. Instead of driving six posts, one next to the other with a two foot space between, and then treating this series with one of the compounds, and in the same row putting in the untreated posts cut from the same sticks as the treated pieces, a distribution scheme was used whereby all of the pieces were scattered over the lot selected for this test. Each of the 344 pieces had a number given to it. These numbers were put into a box, and as each tag with the various numbers was taken, that respective piece was driven. The idea is to have the controls and treated pieces scattered over the field so that they might all be subject to possible termite attack, instead of having them all concentrated in one place where there might be no termites. The committee has on file a chart giving the location of each piece together with the treatment used so that individual pieces may be identified at any time. As was the case in the first series of tests, great care was taken to get pieces of two-by-fours long enough so that untreated control pieces and pieces treated by various soil poisons could be cut from the same pieces of two-by-fours. In a report of this character it does not seem necessary to give all of the details because it would be too voluminous. However, all of these factors are on file for attention at the time of making a final report on the results.

As a matter of ready reference the following list gives all of the series of compounds finally prepared and used. In this tabulation, the word "control" means posts without any treatment or posts around which no soil poison was poured. The word "poured" means the respective solution was poured on the soil immediately around the posts, except in special instances where specific reference is made to circles 20 in. in diameter around the posts.

Pinola
1A—Soaked
1B—Controls
2A—Poured
2B—Controls

Trichlorbenzene
4A—Controls
4B—100 percent poured
4C— 80 percent trichlorbenzene 20-percent kerosene poured
4D—Controls
4E—50-percent trichlorbenzene 50-percent kerosene poured
4F—25-percent trichlorbenzene 70-percent kerosene poured
4G—10-percent trichlorbenzene 90-percent kerosene poured
9A—500 cc. of 10-percent trichlorbenzene 90-percent petroleum poured
9B—1000 cc. of 5-percent trichlorbenzene 95-percent petroleum poured in a circle 20 in. in diameter around posts
9C—Controls
9D—2000 cc. of 5-percent trichlorbenzene 95-percent petroleum poured in a circle 20 in. in diameter around posts
9E—1000 cc. of 10-percent trichlorbenzene 90-percent petroleum poured in a circle 20 in. in diameter around posts
9F—1000 cc. of 10-percent trichlorbenzene 90-percent petroleum poured
9G—2000 cc. of 10-percent trichlorbenzene 90-percent petroleum poured in a circle 20 in. in diameter around posts

Coal Tar Creosote and Kerosene
4H—50 percent of each poured

Antimite
5A—4-percent solution poured
5B—Controls

Wolman Tanalith U
6 —4-percent solution poured

Zinc Chloride
7 —3.48-percent solution—pieces treated to refusal

Pentachlorphenol (Permatol A)
8A—5-percent solution in fuel oil—pressure treated
8B—5-percent solution in fuel oil—dipped
8C—Controls
8D—5-percent solution in fuel oil—poured

Hooker Solvent T
10A—Poured
10C—Controls

Scafoil
10B—Two brush coats
10C—Controls
10G—Soaked 6 hours

Sharples No. 36 Mixture
10D—Poured
10E—Dipped
10F—Controls

Celcure-Sol
11A—Controls
11B—Pressure treated
11C—Dipped
11D—Open-tank process

Chromated Zinc Chloride

12A—Pressure treated—1.03 lb. per cu. ft.
12B—Controls

Alpha Nitronaphthalene

13A—Poured
13B—Controls

Phenyl Mercury Oleate

13C—Pressure treated—.098 lb. per cu. ft.
13D—Pressure treated—.190 lb. per cu. ft.

Ascu

14A—Pressure treated—0.25 lb. per cu. ft.
14B—Controls
14C—Pressure treated—0.50 lb. per cu. ft.
14D—Controls

Wolman Salts—Triolith

15A—Pressure treated
15B—Controls

Your committee in expressing its appreciation for co-operation to various companies as given on page 507 of Volume 40, wishes to add the following:

Scafoil Corporation for Scafoil;

Sharples Solvents Corporation for No. 36 Mixture;

Grasselli Chemicals Department of E. I. Du Pont de Nemours & Company for two-by-fours, pressure-treated chromated zinc chloride pieces, pressure-treated phenyl mercury oleate pieces, and alpha nitronaphthalene;

American Creosoting Company for Ascu pressure-treated pieces and controls.

The above report is presented as information with the recommendation that the subject be continued.

Railr
Atchison, Topeka
Atlanta, Birmingh
Atlantic Coast Li
Baltimore & Ohio.
Bessemer & Lake
Boston & Maine--
Canadian Nationa
Canadian Nationa
Canadian Pacific–
Canadian Pacific–
Central of Georgia

PRESERVATIVE SURVEY—MARCH, 1938

Railroad	Cross ties				Switch timber				Absorption[1]	Process	Remarks	Bridge ties and lumber				Absorption[1]	Piles				Absorption[1]	Process	Remarks
	Percentage				Percentage							Percentage					Percentage						
	Creo	Pet	Creo	Tar	Creo	Pet	Creo	Tar				Creo	Pet	Creo	Tar		Creo	Pet	Creo	Tar			
Atchison Topeka and Santa Fe	45 50	55 50			45 50	55 50			8 lb 8 lb	Rueping Rueping		45 50	55 50			8 lb for bridge ties, refusal for lumber	45 50	55 50			To refusal To refusal	Full cell Full cell	45-55 New Mexico & Cal plants 50-50 Texas and Kansas plants
Atlanta, Birmingham & Coast			80	20			80	20	2.5 gal per ties, 8 lb switch timber	Rueping				80	20	8 lb			80	20	13 lb Inland, 22 lb. Marine	Rueping	
Atlantic Coast Line	100				100				6 lb	Rueping		100				12 lb to 18 lb	100				18 lb	Full cell	5000 ties experimentally with Wolman salts
Baltimore & Ohio	70	30			70	30			8 lb to 8.25 lb	Boulton and Rueping		100				10 lb to 12 lb 0.3 lb per cu ft Wolman salts	100				12 lb to 15 lb	Full cell	Wolman salts for ties & lumber on steel structures All others creo oil treatment
Bessemer & Lake Erie			80	20			80	20	6 lb	Rueping				80	20	12 lb						Rueping	
Boston & Maine			50 60 80	50 40 20			60	40	7 lb to 8 lb y p ties, 8 lb to 9 lb oak ties 9 to 12 lb birch and maple ties 9 lb for switch timber	Rueping Rueping Lowry Rueping		100				10 to 14 lb for lumber 9 lb to 10 lb for bridge ties			60	40	22 to 26 lb Marine 12 to 14 lb Inland	Rueping Full cell Boulton Lowry	
Canadian National West	50	50			50	50			7 lb crossties 7½ lb switch timer	Rueping		100				8 lb	100				8 lb to 10 lb Inland 16 to 24 lb Marine	Rueping, Full cell	
Canadian National East			60	40			60	40	7 lb crossties 8 lb switch timber			100				8 lb	100				8 lb to 10 lb Inland 16 to 24 lb Marine		
Canadian Pacific—West	50	50			50	50			7 lb	Rueping and Boulton		50	50			7 lb	100				8 lb Inland 14 lb Marine	Burnett Boiling and Rueping	
Canadian Pacific—East			60	40			60	40	0.5 lb zinc chloride, 6 lb to 8 lb	Burnett Rueping	At Calgary plant ties treated 0.5 lb zinc chloride—Burnett.	100				0.5 lb zinc, chloride 8 lb	100				8 lb Inland, 14 lb Marine	Burnett Boiling and Rueping	
Central of Georgia			80	20			80	20	7 lb	Rueping		100		80	20	7 lb bridge ties 5 lb to 18 lb lumber	100				18 lb cu ft	Rueping, full cell	7 lb 80-20 creo tar mixture for bridge ties 5 lb creo for lumber open deck trestles and wharves 18 lb creo for ballast deck trestles
Central of New Jersey	40	60			40	60			8 lb. crossties 9 to 10 lb switch timber	Rueping & Lowry		100				10 to 14 lb	100				12 to 14 lb Inland Refusal Marine	Rueping full cell	
Chesapeake & Ohio				100				100	2.5 gal based on 6x8x8'6" tie	Lowry		100				8 to 16 lb	100				12 to 16 lb Inland 16 to 20 lb Marine	Full cell & empty cell	
Chicago, Burlington & Quincy	50	50			50	50			8 lb	Rueping		100				10 lb posts stringers and caps, 6 lb ties, etc	100				14 lb	Rueping	
Chicago & Eastern Illinois			60	40			60	40	0.86 gal. per cu ft.	Lowry				60	40	1.3 gals. per cu ft			60	40	1.3 to 1.72 gals per cu ft	Lowry	
Chicago Great Western			80	20			80	20	6 lb	Rueping		100				14 lb	100				16 lb	A R E A	
Chicago, Milwaukee, St Paul & Pacific	50	50			50	50			8 lb	Rueping		100				10 to 12 lb	100				10 to 14 lb	Boulton	
Chicago Rapid Transit Co			80	20			80	20	6 lb	Rueping		100				6 lb bridge ties 8 to 12 lb other tbr	100				16 lb	Rueping and full cell	Clean treatment desirable for overhead structures
Chicago & North Western	40	60							8 lb. 0.5 lb. zinc chloride	Rueping & Burnett	All sidetrack & softwood ties & switch tbr treated with 0.5 lb Zn Chl per cu ft.	40	60			8 lb minimum	100				10 lb minimum	Boulton & Rueping	
Chicago, Rock Island & Pacific			70 60	30 40			70 60	30 40	7.5 lb.					70	30	8 lb bridge ties 10 to 12 lb other lumber			70	30	16 lb		
Cleveland, Cincinnati, Chicago & St. Louis				100				100	2.5 to 3 gal. pine, 2.5 to 3.5 gal. hardwood	Lowry	Absorptions may be exceeded 0.30 gal per tie	100				8 to 10 lb	100				12 lb	Lowry	
Delaware & Hudson			80	20			80	20	6 lb	Rueping				80	20	8 lb			80	20	8 lb	Rueping	Experimenting on beech, birch and maple ties with 8 lb retention, 60% creo 40% tar mixture
Delaware, Lackawanna & Western				100				100	2.5 to 3.5 gal per tie, 10 lb sw tbr	Lowry		100				10 lb	100				10 lb Inland, 16 lb Marine	Lowry	
Denver, Rio Grande Western	50	50			50	50			7 lb	Rueping & Lowry		50	50			10 lb	100				12 lb	Rueping & Lowry	
Duluth, Missabe & Northern	100				100				6 lb	Rueping		100				6 lb						Rueping	
Elgin, Joliet & Eastern	100				100				5 lb	Rueping		100				5 lb bridge ties, 12 lb other lumber	100				6 to 12 lb	Rueping	
Erie			50	50 100			50	50 100	2.5 gal based on 6x8x8'6" tie	Rueping & Lowry	63% treated 50 50, 47% treated 100% tar Propose use 100% tar for ties and switch tbr during 1938	100		50	50	8 lb	100		50	50	8 to 10 lb	Lowry	80% bridge & lumber treated with 50 50 balance with 100% straight creo, 84% piling treated with 50 50, balance with 100% creo
Florida East Coast											Use untreated cypress exclusively			80	20	14 to 16 lb	100				16 to 22 lb		
Great Northern	50	50			50	50			7 lb minimum for ties, 8 lb min for switch	Lowry		50	50			8 lb Minimum	100				10 lb	Lowry	
Illinois Central			60	40			60	40	7 lb	Rueping		100				8 lb for bridge ties, 16 lb for lumber	100				18 lb	Rueping and full cell	
International Great Northern			70	30			70	30	¾ gal per cu ft	Rueping & full cell		100				8 lb for bridge ties & plank, 16 lb other lumber	100				16 lb	Rueping	
Kansas City Southern			60	40			60	40	7 lb	Rueping & Lowry				60	40	15 lb			60	40	15 lb Inland 24 lb Marine	Rueping and Lowry	
Lehigh & New England			60	40			60	40	8 lb.	Lowry		100				8 lb						Rueping	Some lumber, ¾ lb Z M A
Lehigh Valley			60	40			60	40	2.5 to 3.5 gal per tie 10 to 12 lb Sw tbr.	Lowry		100				10 to 12 lb	100		85	15	15 to 20 lb	Lowry	
Louisiana & Arkansas			80	20			80	20	6 lb	Empty cell		100				16 lb	100				Refusal	Empty cell	
Louisville & Nashville			80	20			80	20	7 lb	Rueping		100				12 to 14 lb	100				18 to 22 lb	Full cell	
Maine Central			60	40			60	40	9 lb.	Rueping		100				9 to 14 lb						Lowry	
Missouri, Kansas, Texas			80	20			80	20	6 lb.	Rueping		100				6 lb	100				16 lb	Rueping & full cell	
Missouri Pacific			70	30			70	30	¾ gal per cu ft	Rueping & full cell		100				8 lb ties & plank, 16 lb for other lbr	100				16 lb	Rueping	
Minneapolis & St Louis			80	20					5.5 to 6 lb	Rueping	Use white oak and Washington Fir Sw Tbr unt												Do not treat lumber or piles.
Minneapolis, St. Paul & Sault Ste Marie			80	20			80	20	6 lb. minimum	Rueping		100				8 to 10 lb						Rueping	
Mobile & Ohio			80	20			80	20	6 lb	Rueping		100				14 lb	100				17 lb	Full cell	
Nashville, Chattanooga & St Louis			80	20			80	20	7 lb oak ties, 9 lb gum ties	Rueping		100				16 to 16.5 lb	100				16 to 16.5 lb	Rueping	
National of Mexico	50	50			50	50			7 lb	Rueping		100				9 lb	100				9 lb and up	Rueping & full cell	
New York Central				100				100	2.5 to 3.0 gal pine 2.5 to 3.5 gal Hdwd.	Lowry	Absorptions may be exceeded 0.30 gal per tie	100				8 to 10 lb	100				12 lb	Lowry	
New York, Chicago & St. Louis				100				100	2.5 gal based on 6x8x8'6" tie	Lowry		100				8 to 16 lb	100				12 to 16 lb	Full and empty cell	
New York, New Haven & Hartford				100				100	8 lb	Lowry		100				10 lb	100		80	20	10 to 20 lb	Lowry and Bethel	
New York, Ontario & Western			80	20			80	20	3.125 gal per tie	Lowry		100				10 lb						Lowry	
Norfolk & Western	100				100				6 lb	Rueping		100				6 lb bridge ties, 12 to 18 lb. lumber	100				12 lb Inland, 16 to 18 lb Marine	Rueping and Bethel	
Northern Pacific	45	55			45	55			8 lb	Lowry		100 45	55			8 to 16 lb	100 45	55			16 lb Marine 10 to 14 lb Inland	Boulton & Lowry	Both straight creosote oil & 45-55 mixture used for treating lbr & Inland Piles
Pennsylvania			60	40			60	40	6 lb.	Rueping				60	40	8 lb for bridge ties, 6 to 12 lb other lbr			60	40	12 lb Inland, 20 lb Marine	Rueping & Bethel	
Pere Marquette			50	100 50			60 50	40 50	2.5 gal based on 6x8x8'6"	Lowry		100				8 to 16 lb full cell & empty cell process	100				12 to 16 lb	Full cell & empty cell	
Reading	40	60			40	60			8 lb crossties 9 to 10 lb switch tbr	Rueping & Lowry		100				10 to 14 lb.	100				12 to 14 lb Inland, Refusal Marine	Rueping & full cell	
Seaboard Air Line			70	30			70	30	7½ lb	Rueping		100				20 lb average	100				21 lb average	Full cell	
St. Louis & Southwestern			70	30			70	30	2.5 gal based on No 3 tie 8 lb for switch timber	Empty cell		100				12 lb	100				15 lb	Empty cell	
St. Louis-San Francisco			70	30			70	30	6 to 7 lb crossties 6 to 8 lb switch tbr	Lowry & Rueping		100				8 lb bridge ties, 8 to 15 lb other lbr			70	30	15 to 16 lb	Rueping & Lowry	
Southern			80	20			80	20	8 lb	Rueping				80	20	12 to 16 lb			80	20	12 to 15 lb Inland 16 lb Marine	Rueping & full cell	Will begin using 60-40 Creo-Tar mixture for cross ties latter part 1938
Southern Pacific	55	45			55	45			8.75 to 9.25 lb	Rueping		55	45			8 to 12 lb, 1 lb. Chromated zinc chloride	100				12 to 15 lb	Boulton & full cell	Bridge ties for steel bridges treated with 1 lb. Cr Zn Chl. per cubic foot.
Tennessee Coal, Iron & R.R. Co.			60	40			60	40	6.25 lb for pine 8.25 lb. for oak	Rueping & full cell				60	40	6.25 lb.			75	25	9 lb	Empty cell	
Texas & New Orleans	70	30			70	30			8 lb.	Rueping		70	30			8 lb	100 70	30			20 to 25 lb. 14 to 16 lb.	Full cell, Rueping	Piles treated with No 1 Creo oil or mixture of 70-30 Creo-Pet
Texas & Pacific			70	30			70	30	7 lb	Rueping		100				16 lb	100				16 lb	Rueping	
Union Pacific	50	50	50	50	50	50			8 lb.	Rueping & Lowry		50	50			8 lb	100				To refusal but not exceeding 16 lb. max.	Full cell or Lowry	
Virginian			80	20			80	20	6 lb.	Empty cell		100				8 lb					16 lb	Empty and full cell	
Wabash			70	30			70	30	2.5 gal based on 6x8x8' tie	Rueping & Lowry		100				6 to 16 lb.	100				12 to 16 lb	Full cell Rueping & Lowry	Combinations with tar used when specifically authorized
Wheeling & Lake Erie			50	50			50	50	6 lb.	Rueping													No lumber or piles treated
Western Maryland			60	40			60	40	6 lb for cross ties 7 lb. for switch tbr	Rueping				60	40	7 lb	100				8 lb.	Rueping	

Appendix D

(9) Present Practice as to Preservatives Used

M. F. Jaeger (chairman, subcommittee), Walter Buehler, H. R. Condon, W. R. Goodwin, L. H. Harper, H. E. Horrocks, R. P. Hughes, Dr. A. L. Kammerer, F. D. Mattos, F. B. Robins.

The committee submits a tabulation summarizing reports received from officers directly responsible for or in charge of treatment, indicating the practice as of March 1, 1938, of the railways listed, also a summary which presents numerically rather than by name, railroads using standard and other than standard preservatives.

This report is submitted as information with the recommendation that the subject be continued and reports be made from time to time as may seem desirable.

SUMMARY OF PRESERVATIVE SURVEY OF MARCH 1938

Railroads in the U. S. A., Canada and Mexico Which Use Coal Tar Creosote and Its Various Mixtures for the Treatment of Their Different Timbers

	Cross Ties	*Switch Ties*	*Bridge Ties & Lumber*	*Piles*
(A)—Straight Distillate Creosote	4	4	40	40
(B)—Creosote-Coal Tar Solutions				
80% Creo.—20% Coal Tar	15	15	5	3
75% Creo.—25% Coal Tar				1
70% Creo.—30% Coal Tar	7	7	1	2
60% Creo.—40% Coal Tar	9	10	5	4
50% Creo.—50% Coal Tar	1	1		
80–20, 60–40 and 50–50 Sols.*	1			
80–20 and 50–50 solutions*	1			
70–30 and 60–40 solutions*	1	1		
60–40 and 50–50 solutions*		1		
(C)—Straight Creosote and Creosote-Coal Tar Sols.				
Creosote and 85–15 solution*				1
Creosote and 80–20 solution*			1	1
Creosote and 50–50 solution*			1	1
(D)—Straight Coal Tar	6	6		
(E)—Creosote-Coal Tar Solution and Straight Coal Tar				
50–50 Solution and Coal Tar*	2	1		
(F)—Creosote-Petroleum Mixtures				
70% Creo.—30% Petroleum	2	2	1	
55% Creo.—45% Petroleum	1	1	1	
50% Creo.—50% Petroleum	6	6	3	
45% Creo.—55% Petroleum	1	1		
40% Creo.—60% Petroleum	3	2	1	
50–50 and 45–55 Mixtures*	1	1	1	1
(G)—Straight Creosote and Creosote-Petroleum Mixtures				
Creosote and 70–30 mixture*				1
Creosote and 50–50 mixture*			1	
Creosote and 45–55 mixture*			1	1
(H)—Creosote-Coal Tar Solution and Creosote-Petroleum Mixtures				
60–40 Creo.-Tar and 50–50 Creo.-Pet.*	2	2		
Number of railroads reporting	63	61	62	56

*—Each material whether straight creosote, straight coal tar, solution or mixture is used separately.

Report of Committee I—Roadway and Ballast

A. E. Botts, *Chairman,*
F. W. Alexander
E. J. Bayer
E. J. Beugler
F. W. Biltz
H. F. Brown
G. H. Burnette
Paul Chipman
A. P. Crosley
L. J. Drumeller
R. L. Dyke
Herbert Ensz
J. A. Given
A. T. Goldbeck
F. L. Guy
A. Haertlein
F. W. Hillman

A. R. Jones
R. B. Jones
O. N. Lackey
G. E. Ladd
H. W. Legro
E. R. Lewis
P. J. McCarthy
Paul McKay
W. S. Moore
C. P. Nicholson
J. A. Noble
M. C. Patton
G. W. Payne
J. M. Podmore
T. P. Polson
W. C. Pruett

A. D. Kennedy, *Vice-Chairman,*
C. S. Robinson
L. H. Roden
L. S. Rose
E. M. Smith
W. C. Swartout
Raymond Swenk
H. M. Swope*
H. E. Tyrrell
Stanton Walker
G. B. Wall, Jr.
C. S. Wicker
P. H. Winchester
A. H. Woerner
G. E. Yahn

Committee.

---

* Died September 13, 1939.

To the American Railway Engineering Association:

Your committee respectfully reports on the following subjects:

1. Physical properties of earth materials, particularly
   (a) Their effect upon roadbed performance.
   (b) Structural bearing power.
   Progress in study—no report.
2. Natural waterways, particularly
   (a) Drainage areas, water runoff, and size of openings (Appendix A). Submitted as information.
   (b) Prevention of erosion. Progress in study—no report.
3. Culverts, particularly
   Vitrified clay pipe culverts. Specification (Appendix B). Submitted as information.
4. Formation of the roadway, particularly
   Settlement; shrinkage, subsidence. (Appendix C). Submitted as information.
5. Roadway drainage.
   Progress in study—no report.
6. Roadway protection, particularly
   (a) Slope protection, including protection against slides and rock falls, collaborating with Committee II—Signal Section, AAR (Appendix D). Recommended for adoption and publication in the Manual.
   (b) Retaining structures
      (a) Cribbing; timber; concrete.
      (b) Walls; dry rubble; masonry.
   Progress in study—no report.
7. Tunnels, particularly
   Lighting (Appendix E). Presented as information.

Bulletin 416, February, 1940.

8. Fences, particularly
    Fence post and braces.
    Corrosion-resisting fence wire, collaborating with appropriate subcommittee of Committee A-5 on Corrosion of Iron and Steel, ASTM (Appendix F).
    Progress report.
9. Signs, particularly
    Close clearance sign.
    Design of signs.
    Specification and plans for telltales—overhead and side.
    Progress in study—no report.
10. Ballast
    (a) Section design (Appendix G). Recommended for adoption and publication in the Manual.
    (b) Develop relationship of ballast materials between service behavior and results obtained from Los Angeles testing machine. Progress in study—no report.
    (c) Investigate the use of asphalt in ballast (Appendix H). Presented as information.
11. Effect of locomotive blow-offs on track maintenance, collaborating with Committee 13—Water Service, Fire Protection and Sanitation. Progress in study—no report.
12. Revision of Manual (Appendix I).

THE COMMITTEE ON ROADWAY AND BALLAST,
A. E. BOTTS, *Chairman.*

Harold M. Swope

Harold M. Swope, division engineer of the Atchison, Topeka & Santa Fe Railway, Emporia, Kan., died on September 13, 1939.

Mr. Swope was born at Emporia, Kan., on December 1, 1891, and entered the employ of the Santa Fe in November, 1913, as a rodman. Following service in this capacity and as masonry inspector, transitman and office engineer on various divisions of the railway, he was promoted in March, 1921, to division engineer, the position he occupied at the time of his death.

Becoming a member of the American Railway Engineering Association in 1929 he was assigned to the Committee on Roadway and Ballast, which committee he served faithfully until the time of his death. Thoroughly imbued with the scientific point of view and given to a thorough study of problems presented to him, his work and counsel were valued highly by his associates on the committee.

The Committee on Roadway and Ballast wishes to record here its appreciation of his many estimable qualities and the profound regret occasioned by his death.

A. E. BOTTS, *Chairman.*

Appendix A

(2) Natural Waterways

Particularly Drainage Areas, Water Runoff, and Size of Openings

L. S. Rose (chairman, subcommittee), E. J. Bayer, R. B. Jones, C. P. Nicholson, J. A. Noble, G. W. Payne, T. P. Polson.

203. SIZE OF WATERWAY OPENINGS

A. FORMULAS

After all available data have been collected for the area under consideration the next step in determining the proper size of a waterway opening is to reduce these data to the quantity of water in cubic feet per second which will reach the opening. Where no record of actual runoff measurement is available this is done with the aid of a runoff formula or by tables or curves developed from formulas.

Many years of research have failed to develop a single formula which is applicable, with any degree of accuracy, to all conditions. A bewildering number of factors, constants and variants have been more or less ingeniously combined to make various formulas fit the needs of given conditions. Nearly all such formulas contain some coefficient C which groups many of these variables and the user is left with the problem of an accurate evaluation of these factors. Text books, scientific papers and published discussions all indicate that every runoff formula in more or less common use today has been qualified either by the author, who has pointed out its limitations, or by other authorities who have been free in their criticism. It is therefore apparent that the selection of a formula and its factors must be made in each case with excellent judgment backed by experience and careful observation.

Former reports of this committee contain practically all the formulas in use today, with descriptive matter setting forth their limitations and usage. These will not be repeated, but an understanding of the basic principles from which most of these formulas evolve may be of value.

A study of runoff data in cubic feet per second platted against the square miles of drainage areas, as analyzed by Jarvis,[1] indicates the relation,

$$q = \frac{C}{M^{\frac{1}{n}}}$$

in which C and n are constants, M representing the square miles of drainage area and q the runoff in cubic feet per second per square mile (See Fig. 1). Some authorities do not agree with this conclusion, the principal reason being that it is based upon only one factor of runoff, i.e., that of area. It is believed, however, that with the large number of observations made and for the purpose intended it does indicate the trend.

Based upon the above equation, the total runoff from the basin then would be

$$qM = \frac{C}{M^{\frac{1}{n}}}, \text{ or } Q = CM^{\frac{n-1}{n}}$$

This fundamental form is followed, with slight variations, by many of the widely used formulas in which n generally takes a value between 1.5 and 6, and results in expressions such as $\sqrt[3]{M}$ and through to $\sqrt[6]{M^5}$. For example, where $n = 4$, $Q = CM^{\frac{4-1}{4}} = Q = CM^{\frac{3}{4}}$ or $Q = C\sqrt[4]{M^3}$.

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[1] Paper No. 1589—Flood Flow Characteristics—ASCE Transactions Vol. 89, 1926.

In an attempt to reduce the many formulas to a common ground for comparison Jarvis has selected the Myers type for modification and extension. In Myers formula $a = C\sqrt{A}$ in which a equals the necessary area of opening, if velocity of flow is assumed at 10 feet per second, A equals the area of the drainage basin in acres, and C is a coefficient varying from 1 to 4. Changing the area from acres to square miles; $a = C \times 25.3 \frac{\sqrt{A}}{640}$ or $a = C \times 25.3 \sqrt{M}$. Then assuming $C = 40$ we have approximately $a = 1{,}000 \sqrt{M}$ and substituting Q, quantity, for a, area of opening, $Q = aV$ or, with a 10-ft. velocity, $Q = 10{,}000 \sqrt{M}$. The resulting graph for Q, correlated with recorded flood flows (Fig. 1) is found to lie above all but two platted points representing runoff rates and to conform closely with the enveloping curve, thus justifying the assumption of $C = 40$ for maximum. This indicates that Myers maximum of $C = 4$ would correspond to 10 percent of the maximum enveloping curve in Fig. 1.

Similarly for lower limits the path of the point, $Q = 100\sqrt{M}$, conforms well with the general slope and lies above only 5 percent of the more than 1,000 platted flood runoff rates.

The wide range between the maximum and minimum curves illustrates clearly the need of excellent judgment and careful consideration of all available data before any important waterway structure is designed. As further evidence, recent studies made by U. S. Army engineers, using the formula $Q = C\sqrt{M}$, indicates the danger of transferring a coefficient, which has been determined by actual measurements, from one watershed to another nearby or even to different areas in the same watershed. For example: the curve for the upper Susquehanna basin follows the formula $Q = 2{,}840 \sqrt{M}$ for areas from 10 to 300 square miles, but for the remaining portion of the curve the coefficient gradually increases until at 10,000 square miles it reaches a value of 4,000. Certain sections of the area have coefficients varying from 1,700 to 2,500 and in the Finger Lakes region they run as high as 6,000.

Only the basic type of formula as correlated to actual measured flood discharges has been considered. For a graphic illustration of the relationship between this formula and other best known expressions of runoff see Fig. 2.

A very important factor in determining the quantity of runoff for which a structure is to be designed is that of the time element or periodic expectancy of flood flows. Unfortunately stream flow records cover only a comparatively recent period and do not yet permit the establishing of a dependable flood cycle if such a cycle actually exists. For convenience floods of different magnitude are classified as 1, 10, 100 or 1,000-year floods. It should be kept in mind, however, that the 100-year flood may occur next year, followed a year later possibly by the 1,000-year flood. Several formulas have been advanced for determining the relationship of major floods of T years to those of a one year maximum. Jarvis in his paper, referred to above, treats of this subject.[2] In spite of the fact that no assurance can be had as to when so-called great floods will occur a flood of some fixed maximum in most cases must be selected for design. This selection should be based upon the following.

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[2] See also, Flood Flows by Allen Hazen—Relief from Floods by Alvord and Burdick.

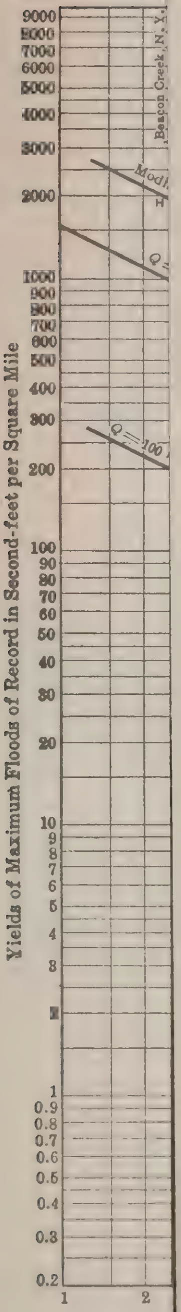

Yields of Maximum Floods of Record in Second-feet per Square Mile
9000
8000
7000
6000
5000
4000
3000
2000
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
1
2
Beacon Creek, N. Y.
Q=100

PLATE IX
TRANS., AM. SOC. CIV. ENGRS.
VOL. 89, PAPER No. 1589.
JARVIS ON
FLOOD FLOW CHARACTERISTICS.

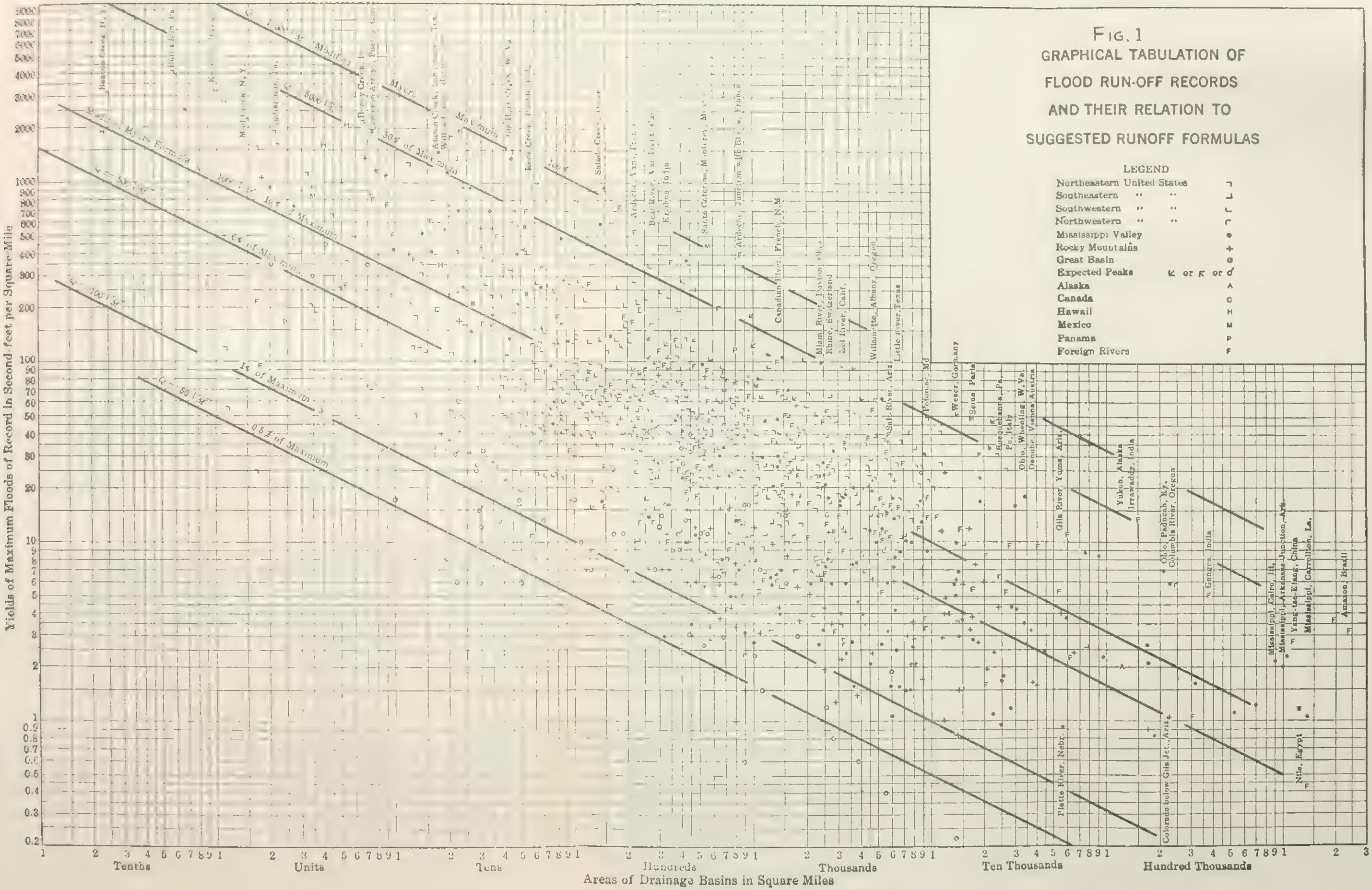
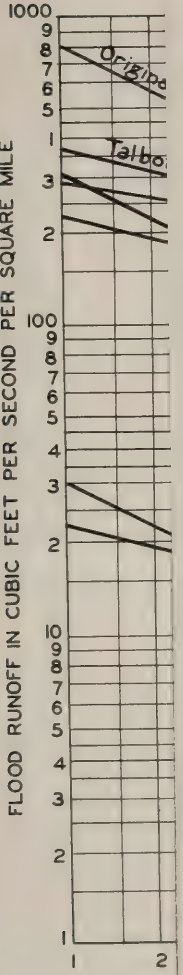


FIG. 1

GRAPHICAL TABULATION OF FLOOD RUN-OFF RECORDS AND THEIR RELATION TO SUGGESTED RUNOFF FORMULAS


FLOOD RUNOFF IN CUBIC FEET PER SECOND PER SQUARE MILE
1000
9
8
7
6
5
4
3
2
100
9
8
7
6
5
4
3
2
10
9
8
7
6
5
4
3
2
1
1
2
Origina
Talbo

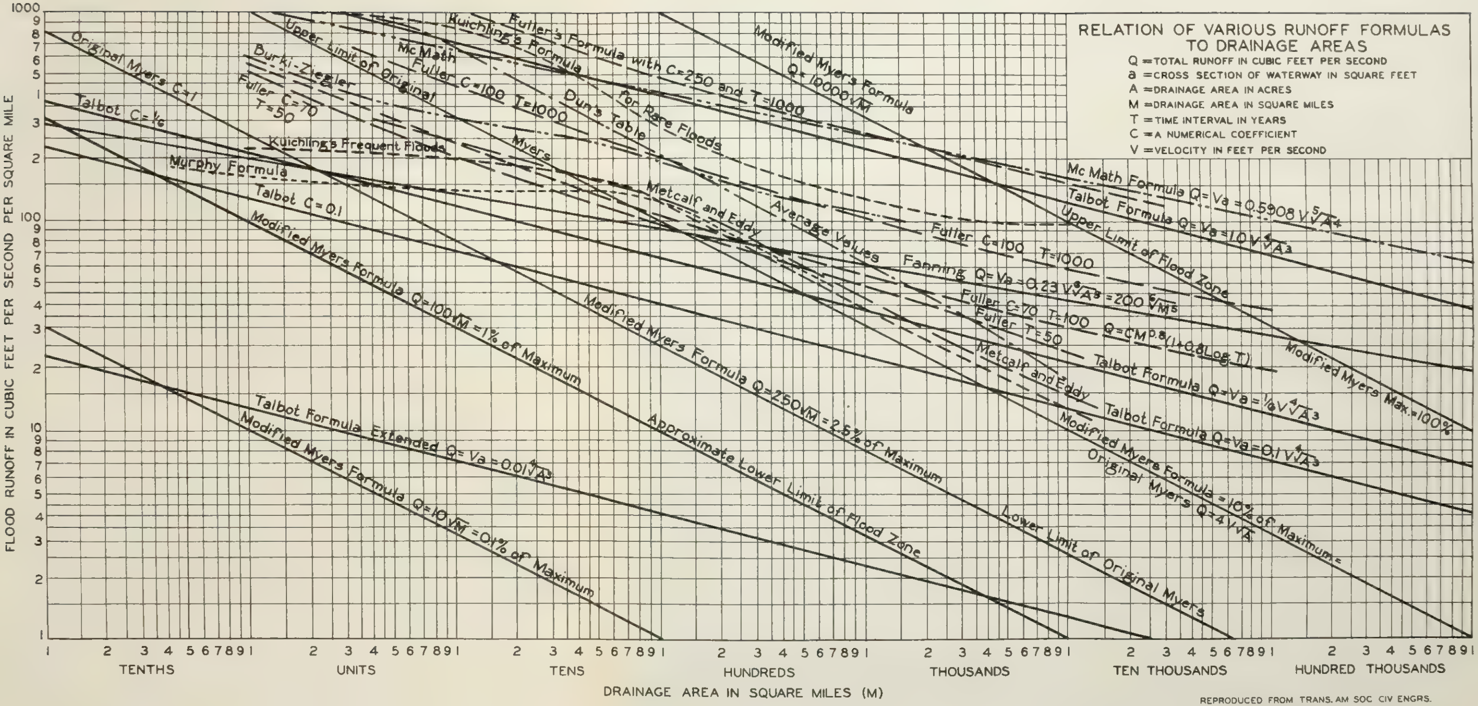


FIG. 2

REPRODUCED FROM TRANS. AM SOC CIV ENGRS. VOL 89 - PAPER NO.1589 BY C.S. JARVIS ON FLOOD FLOW CHARACTERISTICS

(a) First cost of structure
(b) Importance of structure
(c) Available detour lines
(d) Probable duration of flood flows
(e) Time required for replacement and cost
(f) Probable damage from back water
(g) Available overflow channels and areas.

SIZE OF OPENING

After the quantity of runoff has been determined for which the structure is to be designed the wetted area of the opening then becomes $a = \frac{Q}{V}$, in which Q = the total yield of the watershed and V = velocity of flow in feet per second. In most runoff formulas which solve direct for *a, V* is assumed at ten feet per second. This figure however should not be taken arbitrarily. Consideration should be given to the average rate of flow above and below the opening, the nature of the channel material and the bridge foundation. In many cases, to avoid erosion the velocity should not exceed two or three feet per second. It should also be kept in mind that if the hydraulic gradient of the stream is to be maintained no portion of the computed area should be above the elevation of the flood crest. In general this results in low structures of long spans for wide streams and high structures of shorter spans for narrow gorges. For culverts, the elevation of the flood crest may necessitate a battery of smaller pipes instead of a large one of equivalent area.

CONCLUSIONS

Runoff formulas for determining the required sizes of waterway openings, although not recommended, may be used where structures of low cost and minor importance are involved, and when the formula is applied with an appreciation of its limitations, its use is intended only as a guide, and the results are to be modified as other known data and experience seem to demand.

This report is presented as information.

Appendix B

(3) Culverts, Particularly Vitrified Clay Pipe Culverts

W. C. Swartout (chairman, subcommittee), F. W. Biltz, J. A. Given, Paul McKay, M. C. Patton, G. W. Payne, L. H. Roden, E. M. Smith.

Last year your committee reported that the American Society for Testing Materials had a vitrified clay pipe specification, C 13–35, which was issued as a tentative standard in 1917, adopted in amended form in 1920 and revised and adopted as standard in 1924 and 1935. This specification covers a single class of pipe, namely, that which is commonly known as "Double Strength" and used generally in sewer construction. This class of pipe, up to a short time ago, was the heaviest or strongest vitrified clay pipe available, and large quantities of it have been used in culvert work.

Vitrified clay pipe is a rigid pipe and its ability to resist vertical loads is limited by the strength of the pipe ring or barrel to resist external and nonuniformly applied pressures; this may be called the inherent strength. The inherent strength of double-strength pipe is not great enough for the loads imposed in many locations, with the result that structural failures have frequently occurred.

To meet this condition the industry has developed, and is now producing a much heavier pipe in internal diameters 12 to 36 in. and known as "Triple Strength" or "Culvert Pipe." No technical or engineering society has adopted a specification for this pipe, although a subcommittee of ASTM Committee C 4 has had one in preparation for some time. Your committee has collaborated with this subcommittee, but as it is doubtful if the ASTM specification will be completed in time for the March meeting of ASTM committees, your committee deemed it advisable to proceed independently in the preparation of a specification in order that AREA members may have one for use in the purchase of such pipe.

This specification was adapted from the ASTM specification for sewer pipe C 13–35, to the extent that that specification is applicable to the heavier culvert pipe.

It is suggested that pipe of this character would be suitable for use in industrial areas where there are many manufacturing wastes which attack any ferrous metal and concrete structures. A ferrous metal culvert, to give a reasonable service life, must have an asphalt coating which will remain intact and furnish an unbroken envelope under all conditions of service. Vitrified clay pipe will be found suitable in any location if the following requisites are met:

(a) Requisite strength to resist structural failure
(b) Sufficient waterway to avoid necessity for multiple openings
(c) Adequate size to pass without manual assistance all drift which may be anticipated
(d) Resistance to industrial wastes destructive to other types of structures

This specification is offered as information this year for the purpose of inviting criticisms and suggestions with the thought of submitting it, with any revisions deemed desirable, at the 1941 convention for adoption and inclusion in the Manual.

III CULVERTS

302. VITRIFIED CLAY PIPE CULVERTS

A. SPECIFICATIONS FOR VITRIFIED CLAY CULVERT PIPE

Extra Strong or Triple Strength
Adapted from ASTM Specification C 13-35

GENERAL

1. Scope

These specifications cover vitrified clay pipe intended to be used for the construction of culverts and other projects where conditions require that extra-strength pipe be used.

2. Materials

(a) Clay pipe shall be manufactured from surface clay, fire clay, or shale or a combination of these materials.

(b) These materials or any combination thereof, when molded into pipe and subjected to suitable temperatures, shall produce a product that will be strong, durable, serviceable, free from objectionable defects and shall conform to these specifications.

RESISTANCE TO ACTION OF ACIDS

3. Resistance to Action of Acids

The following tests as to the resistance of clay culvert pipe to the action of acids may be prescribed.

When testing with either hydrochloric, nitric, sulfuric or acetic acid, as specified by the purchaser, the acid having a normality of one 1.0 N[1], the percentage of acid-soluble matter shall not exceed 0.25 percent, calculated as sulfates. The purpose of this test is to determine the resistance of pipe to the action of acids and its use is optional.

4. Test specimens

Where possible the specimens intended for these tests shall be selected from pipes which have been previously subjected to the crushing strength test. Specimens shall be sound with all edges freshly broken, free from cracks or shattered edges, about 2 inches square, not weighing more than 200 g. and shall be thoroughly cleaned with a wire brush.

5. Number of Tests

A test shall be made on at least one specimen cut from each size of pipe. The results shall be reported separately for each individual specimen.

6. Weighing Apparatus

The weighing shall be made on a balance accurate to 0.01 g. when loaded with 200 g.

7. Test Procedure

(a) Specimens to be tested shall be dried to constant weight at a temperature of from 210 to 230 degrees F.

(b) The specimens upon reaching constant weight shall be completely immersed in the test solution at a temperature of from 70 to 90 degrees F. for a period of 48 hours, then removed from the solution, carefully and thoroughly washed with hot water, allowing the washings to run into the solution in which the specimen was immersed. This solution shall be filtered and to the filtrate shall be added 5 ml. of concentrated sulfuric acid. This solution shall then be evaporated (avoiding loss of spattering) to about 5 ml.; transferred to a porcelain crucible (previously ignited to constant weight) and heated cautiously to dryness. It shall then be ignited to constant weight.

8. Calculation

The weight of the residue in the porcelain crucible divided by the weight of the dry specimen before immersion, multiplied by 100, is the percentage of acid-soluble matter calculated as sulfates.

$$\text{Percentage acid-soluble matter} = \frac{\text{Wt. of dry specimen in grams.}}{\text{Wt. of residue in grams} \times 100}$$

PHYSICAL PROPERTIES AND TESTS

9. Physical Requirements

The crushing strength and absorption of clay culvert pipe shall conform to the requirements given in Table 1. The individual results of the various tests for each size of pipe and for each shipment shall be tabulated separately so as to show the percentage which fails to conform to the requirements of each test.

10. Test Specimens

The specimens for purpose of tests shall be sound full-size pipe and shall be selected by the purchaser or his representative at the point or points designated by him when placing the order.

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[1] The following percentages are required to make an acid of a normality of one: sulfuric acid, 4.90 percent; hydrochloric acid, 3.65 percent; nitric acid, 6.30 percent; acetic acid, 6.00 percent.

11. Number of Tests

(a) The manufacturer or seller shall furnish specimens for test, without charge, up to 0.5 percent of the number of pipes in each size of pipe furnished, except that in no case shall less than two specimens be furnished.

(b) In any case where more than five specimens are required for testing, not more than five specimens shall be crushed to the point of failure. All specimens in excess of five which show a testing strength of 10 percent above the requirements of this specification shall be removed from the testing apparatus without being broken.

12. Measurement and Observation of Specimens

The specimens taken from pipe tested to destruction, shall be first free from all visible moisture. When dry, each specimen shall be measured and inspected. The results of these observations shall be recorded.

13. Defective Specimens

Specimens which are observed to have fire cracks or other defects in form or dimensions in excess of the limits permitted in these specifications, shall be discarded and replaced with additional specimens from the shipment.

Table 1

Physical Test Requirements of Clay Culvert Pipe

Internal Diameter, Inches	*Average crushing strength minimum, Pounds per Linear Foot*		*Average Absorption Maximum Percent*
	Three-Edge Bearing Method[1]	*Sand-Bearing Method*[2]	
12	2,000	2,860	8
15	2,500	3,570	8
18	3,000	4,290	8
21	3,500	5,000	8
24	4,000	5,710	8
27	4,500	6,430	8
30	5,000	7,140	8
33	5,500	7,860	8
36	6,000	8,570	8

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[1] See Section 16.
[2] See Section 17.

CRUSHING STRENGTH

14. Crushing Strength Tests

Pipe shall be tested for crushing strength by either the three-edge-bearing method or the sand-bearing method. Either of the two specified bearing methods shall be used on retests as provided for in Section 24 (a) and (b).

15. Application of Load

(a) Any prime mover or hand power which will apply the load at a uniform rate of about 2,000 pounds per minute or in increments of not more than 100 pounds at the same rate, may be used in making the test.

(b) The center of the load shall be applied to the top bearing block at a point distant from the spigot end of the pipe equal to one-half of the over-all length of the pipe. The test load shall be applied to the upper bearing block in such a way as to leave the bearing free to move in a vertical plane passing midway between the lower bearings. In testing pipe that is "out of straight," the lines of the bearings chosen shall be free from those which appear to give most favorable conditions for fair test.

(c) The pipe shall not be allowed to stand under load longer than is required to apply the load and to observe and record it.

(d) The testing machine shall be substantial and rigid throughout, so that the distribution of the load will not be affected appreciably by the deformation or yielding of any part. The bearings shall be sufficiently rigid to transmit and receive uniform loads throughout their lengths without deflection, and shall be so attached to the machine as to transmit and receive the maximum loads produced by the tests without lost motion, vibration, or sudden shock.

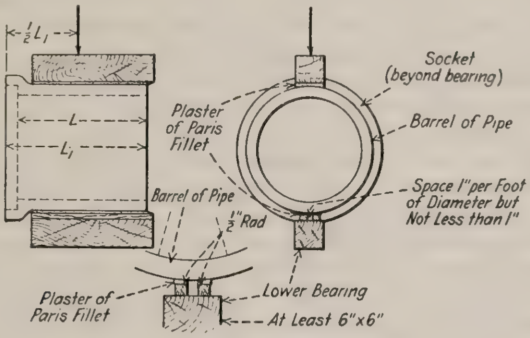

Fig. 1.—Three-Edge Bearings.

(e) The bearings and the specimen shall be accurately centered so as to secure a symmetrical distribution of the loading on each side of the center of the pipe in every direction.

(f) The load shall be applied until the pipe yields by cracks passing through the shell.

(g) The crushing strength shall be calculated by dividing the total load required to break each pipe by the net inside length of the barrel of the pipe, measuring from the bottom of the socket to the end of the spigot.

16. Three-Edge-Bearing Method

When the three-edge-bearing method (See Fig. 1) is used, the ends of each specimen of pipe shall be accurately marked in halves of the circumference prior to the test. The two lower bearings shall consist of two wooden strips with vertical sides having their interior top corners rounded to a radius of approximately ½ inch. The strips shall be straight and securely fastened to a rigid block at least 6 by 6 inch in cross-section. The interior vertical sides of the strips shall be parallel and a distance apart of 1 inch per foot of pipe diameter but in no case less than 1 inch. Before the pipe is placed, a fillet of plaster of Paris or other equalizing material, such as sand and sulfur, thick enough to compensate for the inequalities of the pipe barrel shall be cast on and between the two lower bearings. The pipe shall be placed on the fillet while the plaster of Paris is still somewhat plastic. The use of the plaster of Paris fillet may be dispensed with when mutually agreeable to the manufacturer and the purchaser. The upper bearing shall be a rigid wooden block at least 6 by 6 inch in cross-section, straight and true from end to end. A fillet of plaster of Paris thick enough to compensate for the inequalities of the pipe barrel shall be cast along the length of the crown. The upper bearing shall be brought in contact while the plaster of Paris is still somewhat plastic. The upper and lower bearings shall extend the full length of the pipe exclusive of socket.

17. Sand-Bearing Method

When the sand-bearing method (see Fig. 2) is used the ends of each specimen of pipe shall be accurately marked in quarters of the circumference prior to the test. Specimens shall be carefully bedded, above and below, in sand, for one-fourth the circumference of the pipe measured on the middle line of the barrel. The depth of bedding above and below the pipe at the thinnest points shall be one-half the radius of the middle line of the barrel.

The sand used shall be clean and moist, and shall be such as will pass a 4760-micron (No. 4) sieve.[2] The sand in the lower bearing shall be loose when the pipe is placed.

The top bearing frame shall not be allowed to come in contact with the pipe nor with the top bearing plate. The upper surface of the sand in the top bearing shall be struck off level with a straight edge, and shall be covered with a rigid top bearing plate, with lower surface a true plane, made of heavy timbers or other rigid material, capable of distributing the test load uniformly without appreciable bending. The test load shall be applied at the exact center of this top bearing plate in such a manner as to permit free motion of the plate in all directions. For this purpose a spherical bearing is preferred, but two rollers at right angles may be used. The test may be made without the use of a testing machine by piling weights directly on a platform resting on the top bearing plate, provided, however, that the weights shall be piled symmetrically about a vertical line through the center of the pipe, and that the platform shall not be allowed to touch the top bearing frame.

The frames of the top and bottom bearings shall be made of timbers so heavy as to avoid appreciable bending by the side pressure of sand. The interior surfaces of the frames shall be dressed. No frame shall come in contact with the pipe during the test. A strip of cloth may, if desired, be attached to the inside of the upper frame on each side, along the lower edge, to prevent the escape of sand between the frame and the pipe.

ABSORPTION TEST

18. Test Specimens

The specimens shall be sound pieces, with all edges broken, and may be from pipes broken in the crushing tests. They shall be from 12 to 20 sq. in. in area, and shall be as nearly square as they can be readily prepared. They shall be free from observable cracks, fissures, laminations or shattered edges.

19. Identification

Each specimen shall be marked so that it may be identified with the pipe used in the crushing strength test from which the specimen was taken. The marking shall be applied so that the pigment used shall not cover more than 1 percent of the total superficial area of the specimen.

20. Number of Tests

One specimen shall be tested of each pipe broken in crushing strength test.

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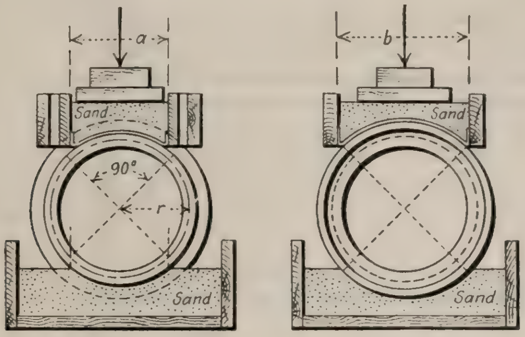
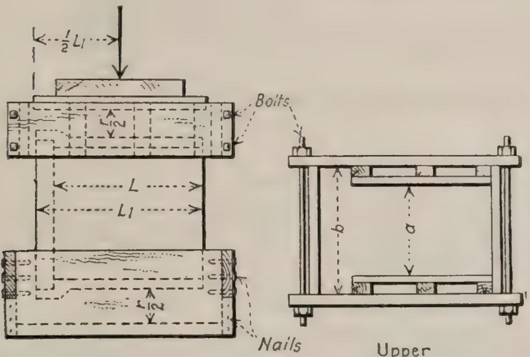
[2] For requirements for this sieve, see Standard Specifications for Sieves for Testing Purposes (ASTM Designation: E-11), 1933 Book of ASTM standards, Part II, p. 1244.



Bedding of Barrel

Bedding of Socket.



Side View.

Upper Bearing Frame.

Fig. 2.—Sand Bearings.

21. Weighing Apparatus

The balance used shall be sensitive to 0.5 g. when loaded with 1 kg. and weighing shall be read to the nearest 1 g. When other than metric weights are used, the same degree of accuracy shall be obtained.

22. Procedure

(a) Drying—Preparatory to the absorption test, the specimen shall be brought to constant weight in a drier or oven at a temperature of not less than 110 degrees C. (230 degrees F.)

(b) Immersion—After reaching constant weight, the specimen shall be placed with other similar specimens in a suitable wire receptacle, packed tightly enough to prevent jostling, covered with distilled water or rainwater, raised to the boiling point and boiled for five hours, and then cooled in water to a final temperature of 15 to 25 degrees C. (59 to 77 degrees F.)

(c) Reweighing—The specimen shall be allowed to drain for one minute, and after the superficial moisture has been removed by towel or blotting paper, the specimen shall be placed upon the balance and weighed.

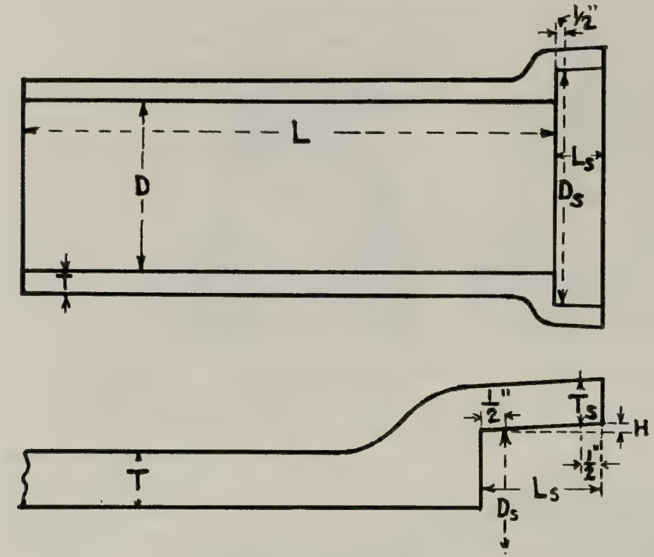


Fig. 3.—Applications of Dimensions Given in Table 2.

23. Calculation and Reporting of Results

The absorption shall be calculated as percentage of the initial dry weight. The results shall be reported separately for each individual specimen, together with the mean for all the specimens from the same shipment of pipe.

24. Acceptance or Rejection on Results of Test

(a) Failure of 20 percent of the specimens to meet the requirements of crushing strength and/or absorption tests shall result in rejection of all the pipe in the shipment or delivery, corresponding to the sizes thus failing to comply; except that in the event of 20 percent of the specimens in any size failing to meet the requirements the manufacturer or seller may, with the consent of the purchaser, furnish for test, without charge, additional specimens from the same shipment. In case more than 80 percent of the specimens tested, including those first tested, shall show substantial conformance for each of the various tests performed, then the entire shipment or delivery for this size shall be accepted; otherwise it shall be rejected.

(b) However, in case of failure of pipe to meet the requirements under the specified method, and the accuracy of the testing machine is questioned, a retest at the request of the manufacturer shall be made upon a machine whose accuracy is known or the machine originally used shall be recalibrated before the retest is made.

(c) In addition to the requirements in Paragraph (a) failure of 10 percent or more of the individual specimens tested to develop 75 percent of the average crushing strength requirements shall be cause for the rejection of the shipment, but the manufacturer or seller may cull the pipe and submit the balance of the shipment for retest, and if the shipment then conforms to all of the requirements of these specifications it shall be accepted.

SIZES, DIMENSIONS AND PERMISSIBLE VARIATIONS

25. Sizes and Dimensions

Pipes shall be furnished of the sizes, internal diameter and with the dimensions given in Table 2.

26. Permissible Variations

The permissible variations from the dimensions given in Table 2 shall not exceed those specified in Table 3. Where the average diameter in the spigot is larger than the nominal size, the average diameter at the inside of the socket shall be increased by the same amount. Where the thickness of the barrel is increased beyond that given in Table 2, in order to meet the specified requirements of strength, the diameter at the inside of the socket shall be increased by double the increase in thickness of the barrel. Pipes intended to be straight shall have a maximum ordinate as measured from the concave side of the pipe not to exceed ⅛ inch per foot of length.

TABLE 2

DIMENSIONS OF CLAY CULVERT PIPE[a]

Internal Diameter (D) Inches	*Laying Length (L) Ft.*	*Inside Diam. at ½ Inch Above Base of Socket (D_s) In.*[b,c]	*Depth of Socket (L_s) In.*	*Minimum Taper of Socket (H:L_s)*	*Thickness of Barrel (T) In.*	*Thickness of Socket (T_s)*
12	3	15⅝	2¾	1:20	1¼	The thickness of the socket ½ inch from its outer end shall be not less than three-fourths of the specified thickness of the barrel of the pipe.
15	3	19¼	2¾	1:20	1½	
18	3	23	3	1:20	1⅞	
21	3	26⅞	3¼	1:20	2¼	
24	3	30⅜	3⅜	1:20	2½	
27	3	34⅛	3½	1:20	2¾	
30	3	37⅝	3½	1:20	3	
33	3	41¼	4	1:20	3¼	
36	3	44¾	4	1:20	3½	

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[a] Applications of dimensions given in this table are shown in Fig. 3.

[b] When pipes are furnished having an increase in thickness over that given in last column, the diameter of socket shall be increased by an amount equal to twice the increase of thickness of barrel.

[c] When the pipes furnished have an average diameter larger than the nominal size, the inside diameter of the socket shall be greater by the same amount than the values given in the third column.

TABLE 3

PERMISSIBLE VARIATIONS IN DIMENSIONS OF CLAY CULVERT PIPE

Limits of Permissible Variation in:

Nominal Size Internal Diameter, in.	*Length, inches per ft. (—)*	*Lengths of Two Opposite Sides, inches per foot of length*	*Internal Diameter inches*		*Depth of Socket in. (—)*	*Thickness of Barrel in. (—)*
			Spigot (+ or —)	*Socket (+ or —)*		
12	¼	3/16	5/16	⅜	¼	⅛
15	¼	3/16	5/16	⅜	¼	⅛
18	¼	3/16	7/16	½	¼	⅛
21	¼	3/16	½	9/16	¼	⅛
24	⅜	¼	9/16	⅝	¼	3/16
27	⅜	¼	⅝	11/16	¼	3/16
30	⅜	¼	⅝	11/16	¼	3/16
33	⅜	¼	11/16	¾	¼	¼
36	⅜	¼	¾	13/16	¼	¼

Note—The minus sign (—) alone indicates that the plus variation is not limited, the plus and minus sign (+ or —) indicates variation in both excess and deficiency in dimensions.

WORKMANSHIP AND FINISH

27. Absence of Defects

Pipes shall be substantially free from fractures, large or deep cracks and blisters, laminations and surface roughness.

28. Salt Glaze

The glaze shall consist of a continuous layer of salt glaze substantially free from large blisters or large pimples. No blisters shall exceed 3 inches in diameter and no blisters or pimples shall project more than 1/8 inch above the surrounding surface of the pipe for sizes up to and including 18 inches internal diameter. For sizes over 18 inches internal diameter no blisters shall exceed in diameter more than 2 inches per foot of the internal diameter of the pipe, nor project above the surrounding surface of the pipe more than 1/8 inch per foot of the internal diameter of the pipe.

Not more than 10 percent of the inner surface of any pipe barrel shall be bare of glaze except the socket, where it may be entirely absent. Glazing shall not be required on the outer surface of the barrel at the spigot end for a distance from the end of the pipe equal to the specified depth of socket. There shall be no well defined network of crazing lines or hair cracks.

29. Finish of Ends

The ends of the pipes shall be square with their longitudinal axes, except as provided in Table 3.

MARKING, INSPECTION AND REJECTION

30. Marking

Each length of pipe shall bear the initials or name of the person, company or corporation by whom manufactured and the location of the factory. The markings shall be indented on the exterior of the pipe near the socket and shall be plainly legible for purposes of identification.

31. Inspection

All pipes shall be subject to inspection at the factory, site of project or other point of delivery by a competent inspector employed by the purchaser. The purposes of the inspection shall be to cull and reject pipes which, independent of the physical tests herein specified, fail to conform to the requirements of these specifications.

32. Rejection

Pipes shall be subject to rejection on account of the following:

(a) Variations in any dimension exceeding the permissible variations given in Table 3.

(b) Fractures or cracks passing through the shell or socket except a single crack at the spigot end of the pipe not exceeding 75 percent of the depth of the socket, or a single fracture in the socket not exceeding 3 inches measured around the circumference, nor 2 inches lengthwise.

(c) Chips or fractures on the interior of the pipe exceeding 2 inches in length, 1 inch in width, and of a depth more than one-quarter of the thickness of the shell.

(d) Blisters which are broken or which exceed the dimensions specified in Section 28.

(e) Fire cracks or hair cracks sufficient to impair the strength, durability or serviceability of the pipe.

(f) Variation of more than ⅛ inch per linear foot in alinement of a pipe intended to be straight.

(g) Glaze which does not conform with these specifications as specified in Section 28.

33. Marking of Rejected Specimens

All pipes accepted may be plainly marked by the inspector. Rejected pipes shall not be marked so as to be defaced or to impair their value, but shall be replaced by the manufacturer or seller with pipes which meet the requirements of these specifications, without additional cost to the purchaser.

Appendix C

(4) Formation of the Roadway

Particularly Settlement; Shrinkage; Subsidence

Paul Chipman (chairman, subcommittee), E. J. Beugler, F. W. Biltz, Herbert Ensz, Albert Haertlein, G. E. Ladd, Raymond Swenk, H. E. Tyrrell.

402. RECOMMENDATIONS

C. ALLOWANCE FOR SETTLEMENT; SHRINKAGE; SUBSIDENCE

Definitions

Settlement, as applied to grading material, is the reduction in elevation of an embankment due to shrinkage or subsidence.

Shrinkage is the difference in volume between the material excavated and the ultimate volume of the same material in the embankment after it has reached a state of equilibrium, when the latter is the smaller.

Subsidence is that portion of an embankment which has settled below the original surface of the ground.

Settlement is therefore due to two causes which are entirely distinct: Shrinkage, which depends on the characteristics of the material of which the embankment is made; and subsidence, which depends on the characteristics of the material upon which the embankment rests, although its amount may be affected by the kind of material in the embankment.

Previous Reports

The subject of settlement has been thoroughly studied by this committee in the past and its findings are reported as follows:

Manual,		Pages	1–35, 36
Proceedings, Volume	8,	Pages	307– 308
"	18	"	652– 656
"	20	"	411– 415
"	21	"	820– 831
"	22	"	698– 706
"	23	"	395– 397
"	36	"	1091–1162*

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* Landslides, Subsidences and Rock-Falls, by Dr. G. E. Ladd.

Modern Grading Practice

The present material in the Manual was inserted in 1921. Since that time the enormous expansion of the highway system of the United States has involved grading operations of unprecedented extent. The same cause which resulted in this expansion, namely, the substitution of internal combustion engines for animal power, has likewise brought about a revolution in grading practice. There has also been an increasing recognition of the effect of subgrade conditions on track maintenance and a fuller appreciation of the value of a stable roadbed. The disadvantage of subsidence of fills under paved highways brought about new ways of eliminating or reducing it.

The behavior of earth and rock when excavated and deposited in a fill is, of course, the same as always, if attendant conditions are the same; and the subject of settlement is reviewed at this time in order to invite attention to the changed conditions which now prevail and to determine whether previous conclusions and recommendations are in any way invalidated by them.

Allowance for Shrinkage

With the exception of bank widening and of such bridge and trestle filling as can be more economically done by train, all grading of any consequence is now done with trucks, power scrapers, or dump wagons drawn by tractors. The great weight of these machines makes them very effective agents of consolidation, especially if the material is spread in layers. Spreading is done at small expense with a tractor with scraper attachment, either in front (bulldozer) or drawn behind. This operation in itself aids materially in consolidation.

Such methods make for better and more uniform consolidation, and tend to minimize shrinkage after construction; thus adding force to the committee's former recommendation, as set forth in the Manual, that no vertical allowance be made for shrinkage, but that the width be increased by an amount equal to about three times the estimated settlement due to shrinkage.

Although there are many miles of railroad that are operated without disadvantage over fills which have settled and on which the grade of track has never been restored, there are other locations where such a condition has proved so serious as to call for correction. However, such situations are usually due to subsidence rather than shrinkage. With the grading methods that prevail today, the total shrinkage after construction is generally slight and gradual. Its effects on operating costs are negligible, and the small inequalities in gradient that result from it can usually be adjusted in the course of ordinary surfacing of track. The need for a shrinkage allowance is far less than it was when most high fills were made by dumping from trestles. In fact, most line and grade revisions made in recent years have been carried out by modern grading methods that obviate allowance for shrinkage. In one case, involving fills as high as 60 ft., no appreciable settlement has taken place after 2½ years of service.

Spreading Material Dumped From Bridges and Trestles

Where material is dumped from trestles, certain parts of the fill, particularly in the lower portion of it, are consolidated by the impact of the falling material; while other parts, formed by the rolling down of material from higher levels, receive little compaction. This is not so serious a matter with sand or gravel, but with clay or loam, particularly stiff clays, a large part of the ultimate shrinkage takes place after the material is deposited. This may be as little as 5 percent for sand and gravel and as much as 20 percent for stiff clay. The latter material usually occupies more space when freshly placed than it did before excavation. Clay and loam should, therefore, be spread in layers, with adequate compaction of each layer. Some benefit will result from such treatment even with sand and gravel.

Bank Widening

The foregoing also applies to bank widening with material dumped from the track, except that practically all such material rolls down the bank and thus receives even less compaction than material dumped from a trestle. Spreading in layers is not practicable unless the added material has a considerable width, in which case it should be done. If clay is used, rolling is also advisable, as otherwise the settlement will be excessive. If the added prism is too narrow for such treatment, sand or gravel should be used, as pointed out in a previous report of this committee (Vol. 36, p. 313).

Special Compaction

By the use of rollers, combined with sprinkling when required to secure proper moisture content, future shrinkage can be practically eliminated, if the material contains enough clay to permit compaction. Ordinary road rollers may be used for this purpose, but the sheep's foot roller is more effective. Such treatment for earth dams and reservoir walls has been common practice for years, and it has been employed to a considerable extent for railway as well as highway fills. Reference is made also to the practice of settling fills by jetting and ponding, but its use on railway fills has not been extensive. Most grading specifications provide for rolling where required, and there is a tendency to include density requirements which make special compaction obligatory if necessary to meet such requirements.

Total Shrinkage

The foregoing relates to shrinkage after construction, and not to the total shrinkage from volume in excavation to ultimate volume in embankment. Total shrinkage is involved in the estimating and distribution of earthwork quantities and is discussed in previous reports of this committee.

Subsidence

Subsidence may be divided into three classes:

1. That due to the collapse of mines or caves.
2. That due to the compression of the underlying material.
3. That due to lateral displacement of the underlying material.

Subsidence of the first class does not often affect railroads. It must be dealt with as local conditions require. These may be so severe as to necessitate relocation.

Compression

Subsidence due to compression occurs to some extent under all embankments that do not rest upon rock. It is small in amount unless the ground contains a considerable amount of water that may be squeezed out of it by the weight of the fill. Under high fills, most of the subsidence of this class takes place during construction; but under low fills the weight of trains and vibration are relatively larger factors and a greater proportion of the settlement may be expected during operation. In either case, it may continue for several years with gradually decreasing effect. When the ground water level is near the surface during construction and is subsequently lowered by drainage, settlement is apt to occur.

Lateral Displacement

In subsidence due to displacement, the fill settles into the soft material beneath it and displaces it laterally. This type is common in the more recently glaciated sections of the north central states and Canada, but is also encountered in tidewater marshes, swamps, old river beds, and wherever the requisite combination of soil and water is found.

Displacement is always accompanied by compression, a part of the subsidence being due to squeezing out the water, and part to the displacement of the solid elements. If these particles are of such density, size or form that they are not easily moved by the outgoing water, subsidence will be limited to that due to compression, and its amount may be approximated by determining the water content of the material above firm bottom.

If, however, the soil particles are of such nature that the surrounding water is not easily freed from them, the entire mass will be forced outward and upward along the route of least resistance. This will continue until equilibrium is reached between the pressure exerted by the fill and the friction between the soil particles plus the weight of counterbalancing material, some of which will be lifted above the natural ground level. This lifting usually takes the form of ridges, generally near the fill, but not always so, as they will occur wherever the crust of earth and vegetation offers least resistance, sometimes at a distance of several hundred yards.

The soil of swamps, as distinguished from the plastic mud of tidewater marshes, is made up of organic matter, together with clay, sand, and frequently underlaid with more or less marl. The friction of the clay particles having been reduced by saturation, they act as a lubricant for the mass and facilitate its displacement.

Vibration tends to destroy friction, which is one reason why fills that were apparently stable often show settlement after being put in service.

Corduroy

It was formerly common practice in building embankments across swamps to place a layer of poles or logs known as "corduroy" on the surface. There were two types of corduroy in use. One consisted of a layer of poles and brush of only sufficient width and strength to permit starting the embankment, which sank from its own weight as it was built up. This type was used principally for shallow swamps.

For deep swamps and sinkholes, long logs were laid transversely, with their ends extending well beyond the toe of the intended fill. This layer sometimes rested on another layer laid longitudinally, but more often on a few long logs so placed. The fill was then built on this raft and settled until equilibrium was established. The timber required was usually found on the right-of-way, and this method saved much initial expense and time.

Many of these fills have caused little trouble. They have settled slowly and not to an extent that would appreciably affect maintenance or operating costs. Others have been a continual source of trouble and expense. The probability of settlement due to vibration, increased loads, breaking of corduroy, and drainage of swamps, combined with the fact that timber is no longer available at little or no cost, has made these methods obsolete for railroads, and the use of paving has made them unsuitable for highways of the better class.

Data Required

The problem now in making a fill across soft ground is to find how it can most quickly and economically be brought to rest on a firm foundation. The first step in this direction is to determine the depth to firm ground and the characteristics of the soft material above it. This is necessary either for estimating purposes or for decision as to method of treatment. The depth to solid ground may be determined with sounding rods; but unless the characteristics of the soft material are fairly well known from previous experience, an apparatus should be used with which samples at different depths may be taken. A sounding rod point that will meet this requirement if the material is not too liquid, is described on page 699 of Vol. 22 of AREA Proceedings. The highway departments of states where subsidence is common have developed apparatus for making such determinations, which can usually be borrowed for temporary use. A type in common use has been put on the market. Tests should be made on both sides of the fill, as a slope in the firm ground has a marked effect on the amount of subsidence and also has a bearing on the method of treatment.

Where samples show that the material is such as not to be readily displaced, a determination of the water content will aid in estimating the amount it will compress. Doubt as to the behavior of the material can usually be resolved by submitting samples to some one who has had experience with like material.

Allowance for Compression

Where no lateral displacement is anticipated, the lower levels of the fill can be made by end dumping of trucks or by use of a light corduroy. As a rule, the ultimate compression will not be reached during construction, and the fill should be widened by an amount equal to not less than three times the estimated future settlement. No vertical allowance need be made unless borings show a considerable water content in the underlying material.

Accelerating Subsidence

Where displacement may be expected, three general methods have been developed to secure accelerated subsidence:

Explosives.—Explosives are placed below a fill of sufficient depth to serve as a reaction cover for them. Their explosion forces material outward from under the fill, permitting the latter to settle. Additional material is placed on top of the fill and the operation is repeated until a firm bottom is reached. This method has been found to be effective and not unduly expensive. Makers of high explosives employ men who are experienced in this class of work and are available for consultation.

Jetting.—Another method that has proved effective where enough water is available, is to force water into the soft material, thus facilitating its displacement. The jets are usually placed at about one-third of the depth of the soft material and are applied over an area 50 to 75 feet long ahead of the advancing fill and in a row on each side of the unsettled part of it. The latter are directed inward in order to reach soft material not forced out by previous settlement.

Removal of Soft Material.—The third method in common use is the excavation of a short section of the soft material just ahead of the fill, and its replacement by advancing the fill by end dumping. This method has been very successful in the peat bogs of Michigan, and is the one generally used in building the highways of that state. It cannot be used in the rather infrequent cases where the surface of the swamp is too soft to support a dragline carried on a mat. The excavated material is spread at the sides of the completed embankment, the entire operation thus being confined within the reach of the dragline.

Two variations of this method are in use for new fills. In one, the peat is excavated to its full depth and the fill is carried forward at its proper grade. Where the peat is underlaid by marl, the latter is not disturbed, as it has little displacement, but compresses 30 to 50 percent. Under the other plan, the peat is excavated to a part of its depth, usually not less than 6 feet, and the remainder is squeezed forward and upward by the advancing fill to the open section, where it is excavated. The fill is surcharged at its end by an amount liberally estimated to bring it to proper grade when settled to solid ground, any excess being pushed forward over the end of the fill with a bulldozer.

Still another method is used when improving old roads that have been "floated" on corduroy. In such cases the new fill is always wider than the old one. A ditch with slopes as steep as the material will stand is excavated to solid ground on each side of the road metal and filled with good material, thus confining the peat remaining under the old road. These ditches are opened in short sections, the new fill is carried forward to proper width and grade as the ditches are filled, and material excavated is spread at the sides of the fill.

Suitability of Methods—Costs

The trend at present among highway engineers is toward the excavation method; complete for a depth of 6 to 8 feet or more; partial for greater depths not exceeding 20 or 25 feet, and partial excavation supplemented by jetting or blasting for still greater depths.

The cost of such work varies under different conditions. Some materials are displaced easily and others with difficulty. Material compressed under a high fill or an old fill is harder to move than undisturbed material. In Michigan and Minnesota, the average cost per cubic yard displaced has been about 10 cents, with no great variation as between methods, if each has been used where best adapted.

Filling Material

This cost does not, of course, include the filling material, the choice of which is an important matter. It should be sand, gravel, cinders or stone, as clay becomes saturated and is almost sure to be displaced laterally by the weight of the fill above it.

Continuing Subsidence

The foregoing relates principally to new construction. Certain old railroad fills continue to settle year after year, requiring frequent ballast lifts to keep the track in serviceable condition. Such fills have not reached solid bottom, although much material may have been added to them in the course of years. If the original fill was clay, continued settlement may be expected until most of the clay has been displaced by the better material added later.

In considering the possible cure of such cases, the first step is to take soundings and soil samples in order to learn the shape of the underground portion of the fill, the depth to solid bottom, and the nature of both fill and underlying material. It may be found that a continuation of past procedure is the most economical course to pursue.

When it is feasible, drainage will effect an improvement and, if carried deep enough, a cure. The latter is seldom possible, but any considerable lowering of the ground water level will be of help.

The displacement of the soft material and the gradual settling of the fill by jetting would seem to offer some promise for treating cases of this kind. So far as is known, it has not been tried by any railroad. The use of explosives involves a sudden settling of the fill that would be difficult to restore between trains. Settling by jetting is under better control, although some disruption of the fill may be expected.

The method of sinking a fill at each side of the roadway by excavating short sections of the soft material ahead of the fills as they are advanced, thus confining the soft material under the roadway fill, might be found practicable in some cases. Material for the new fills would be handled with trucks, without any interference with traffic.

CONCLUSIONS

1. Where material is spread in layers of one foot or less in thickness, fills made with modern grading equipment are so compact that no vertical allowance should be made for future shrinkage.

2. Where any considerable amount of subsidence is anticipated, particularly subsidence due to displacement, adequate depth tests should be taken and a study of the material made, in order to determine the method of treatment and to make an estimate of the amount of filling material required.

3. Good construction practice will avoid future subsidence by carrying the fill to solid ground by:

(a) Settling the partly made fill by means of explosives or jetting.
(b) Excavating a short section of the soft material and replacing it with suitable material dumped over the end of the advancing fill.
(c) A combination of these methods.

4. Railroad embankments subject to continuing subsidence should be studied to determine whether their stabilization would be economically justified.

BIBLIOGRAPHY

General

See references to AREA publications on page 533.

Earthwork and Its Cost, H. P. Gillette; properties of earth, pp. 1–18; borings and soundings, pp. 41–84; determining shrinkage and subsidence, pp. 1088–1089.

Railroad Construction, Walter Loring Webb; shrinkage of earthworth, pp. 149–152; allowance for shrinkage or subsidence, p. 153.

Shrinkage

Engineering News-Record, Vol. 62, Aug. 12, 1909. Notes on Shrinkage of Earth Work and on Steam Shovel Work, F. Pardoe Wilson; advocates no vertical allowance for shrinkage but widening fills or steepening slopes.

Engineering News-Record, Vol. 83, July 17, 1919, pp. 126–7. Shows sections of old fill on B. & O. R.R., with water pockets.

Engineering News-Record, Vol. 85, Aug. 26, 1920; pp. 418–9; abstract of report of Subcommittee of Presidents' Conference Committee on Federal Valuation, D. J. Brumley, Chairman; Shrinkage and Swell of Material in Railway Fills; measurements by carriers of 12,000,000 c.y. and other data.

Engineering & Contracting, June 16, 1920, pp. 682–3 and Dec. 15, 1920, p. 591; describes extensive tests on C. B. & Q. R.R. as to density and shrinkage.

Railway Age, Vol. 68, June 4, 1920, pp. 1573–7; complete and detailed account of C. B. & Q. tests.

Railway Age, Vol. 101, Nov. 21, 1936; pp. 756–9; construction methods on grades and line revision on C. B. & Q. R.R. at Chariton, Ia.

Subsidence

Peat, C. A. Davis; published by the Geological Survey of Michigan, 1907.

Roads and Road Construction, Dec. 1, 1938; T. F. N. Alexander; Dutch Roadways Constructed upon Compressed Peat Fillings.

Proceedings of Highway Research Board, Vol. 14, 1935, pp. 315–339, Methods and Costs of Peat Displacement, J. W. Kushing and O. L. Stokstad; most comprehensive article now in print.

Explosives Engineer, Vol. 15, June 1937, pp. 181-182; J. Howard Patterson; settling fill at Laurel, Miss. by blasting.

Civil Engineering, Vol. 6, May 1936; Building Roads through Unstable Foundations; J. M. Jeffries; methods of blasting.

Public Roads, Vol. 16, Feb. 1936; F. A. Robison; actual and computed settlement of hydraulic fill over muck on Mt. Vernon Memorial Highway.

Proceedings of 18th Annual Conference on Highway Engineering; University of Michigan Official Publication, Vol. 34, No. 3, pp. 82–95; Latest Developments in Design of Subgrades,—The Peat Marsh Problem. A. C. Benkelman.

Engineering News-Record, Vol. 110, June 1, 1933, pp. 715–717; Chas. R. Moody; settling fill across salt marsh at Portsmouth, R. I. by blasting.

Public Works, Vol. 64, March, 1933, pp. 15–16; Settling a Road Embankment by Underfill Blasting, Carl G. Wahl, (Ohio).

Engineering & Contracting, Vol. 71, June 1932, pp. 149–150; L. F. Livingston; settling fills by blasting.

Engineering News-Record, Vol. 106, Apr. 23, 1931, pp. 687–9; Roads and Streets, Vol. 71, Apr. 1931, pp. 139–144; J. A. Williams; settling fills on plastic mud in tidewater marshes of New Jersey by blasting.

Bulletin of E. I. DuPont de Nemours & Co., Use of Explosives in Settling Highway Fills.

Bulletin of Hercules Powder Co., Accelerating Swamp Fill Settlement With Explosives.

This report is presented as information with the recommendation that the subject be continued.

Appendix D

(6) Slope Protection

Including Protection Against Slides and Rock Falls, Collaborating with Committee II—Signal Section, AAR

C. S. Robinson (chairman, subcommittee), G. H. Burnette, R. L. Dyke, C. P. Richardson, G. W. Payne, W. C. Pruett, M. C. Patton.

As the result of a study of information on this subject obtained from various railroads, states, and the U S. Department of Agriculture, the following deletions and additions to the Manual are recommended for approval:

602—Slope Protection, page 1–4

To Be Deleted

A. by Vegetation. Sodding and seeding. Bush and tree planting.
B. by Surface blanketing. Willow mats. Grouting. Rip rap.
C. by Structural support. Struts. Piling.
D. by Formation. Berms. Terracing. Widening cuts.
E. Against burrowing animals.

Proposed Form

A. by Formation. Widening cuts. Berms. Terraces. Gully control.
B. by Vegetation. Sodding and seeding. Bush and tree planting.
C. by Surface blanketing. Paving cinders. Rip rap.
D. by Detector fences.

602—Slope Protection, page 1–65

To Be Deleted

A. BY VEGETATION

1927

1. The slopes shall be graded to whatever final surface is desired.

2. Vegetation suited to the conditions existing in the territory where slopes are to be protected, shall be selected. This may consist of sod transferred from other locations;

sod grown on slopes, as a result of seeding; vines such as Honeysuckle, Myrtle, etc., and dwarf species of shrubbery.

3. If the material of the slope is not fertile, it may be given a dressing of loam, manure or commercial fertilizer. As manure generally contains weed seeds, care must be taken, where applied, to prevent troublesome weeds from going to seed.

4. In order to prevent newly laid sod, transferred from other locations, from slipping, it is necessary to hold it to the slopes by use of wooden pins not less than 7 inches long, spaced not more than 2 feet apart.

5. A good seed mixture for well watered parts of the country consists of about 50 percent alfalfa, 25 percent Kentucky Blue Grass, and 25 percent of red top seed. Care must be taken to inoculate the alfalfa seed, if the soil has not previously grown alfalfa. Sweet clover is also effective at many locations, and in some sections of the country Bermuda grass is found to be the best.

6. Honeysuckle vines are effective at many locations, recommended spacing of plants being two feet apart.

7. The following species of dwarf shrubbery may be used under certain conditions; Indian currant (Symphoricarpos-Vulgaris); Bittersweet—American; Forsythia (Intermedia).

Proposed Form

A. BY FORMATION

In cuts where the adjacent ground is level, or pitches towards the slope, an adequate berm ditch is required along the top of the slope to keep the water from getting to the slope. A primary consideration in slope protection is to divert or control surface drainage by intercepting ditches and gutters, and adequate underdrainage to correct subsurface saturation.

Widening Cuts.—Where necessary to provide for larger drainage, or when underlying water has to be removed, the width of cuts should be increased accordingly.

Berms.—Berms are valuable on deep cuts where water has a tendency to concentrate, producing gullies. When the excavation is in fine sand, or in other material which erodes easily, paved waterways should be provided at intervals to conduct the water to the subgrade control ditch.

Berms may be used to good advantage in connection with "B"—Vegetation, and "C"—Surface blanketing.

Terraces.—Terraces are of value to reduce the concentration of water and prevent erosion. The use of lateral ditches on terraces provides for the diversion of the water and reduces the erosion on the lower surface of a cut, and permits vegetation to establish itself.

Gully Control.—Gully control requires healing of the gully and may be accomplished by the following procedure:

1. Construction of temporary check dams to catch the loose soil in which to plant trees, vines and grasses.
2. Slope banks to the angle of repose.
3. Plant vegetation that is characterized by rapid growth and spread of roots in the soil.

Temporary check dams should be of permeable construction with such materials as brush, logs, woven wire, and should not as a rule exceed three feet in height.

B—BY VEGETATION

If the vegetation method is to be used the slopes should be reduced to obtain a natural angle of repose.

Sodding and Seeding.—Top soiling, if required, and seeding or sodding, also strip sodding and seeding, may be successfully used. The location of the area, climate, availability and adaptability of materials should govern their selection.

Materials for consideration in seeding and sodding are brome grass, Kentucky blue grass, the clovers, perennial rye, Bermuda grass, Kudzu vines, oats, and orchard grass. A light cover of straw mulch, after the soil has been prepared and seeded, proves of value in getting quick germination and growth.

Native pasture sods may be used. The thinner the turf is cut the quicker the roots will grow down into the soil in its new location.

Sods an inch thick are better than thicker ones, and sodding is best done in rainy weather.

Bush and Tree Planting.—The planting of small shrubs and vines may be successfully undertaken, but the planting of large trees is not recommended due to the danger of added top weight and occasional slippage. Native shrubs and vines can be successfully used. Materials for consideration are the sumacs, roses of all types, black locust, honeysuckle, and willow cuttings.

C—BY SURFACE BLANKETING

Slope protection by surface blanketing is practical and economical. The conditions existing as to angle or repose, surface and subsurface drainage, availability, cost of materials, and permanency, should govern the methods selected.

To cure erosion the following methods of slope protection by surface blanketing should be considered:

Paving.—Paving in instances where slopes exceed natural angle of repose.

Cinders.—Cinder blanket 8 inches to 12 inches thick on clay banks, with cinders carried well to the top of the slope.

Rip Rap.—Rip rap—plain or grouted.

D—DETECTOR FENCES

Slide detector fences are now being used on some roads for protection against hazards caused by land slides, falling rocks, snow and ice, and other materials. One road reports approximately 100,000 feet of such installations at 25 locations and embodying 67 separate fences. Several types of detector fences are in use. Details of construction are covered in Vol. 36 of the Signal Section Proceedings, page 53, and Minutes of the 45th Annual Meeting of the section, page 243.

Appendix E

(7) Tunnels, Particularly Lighting

F. W. Alexander (chairman, subcommittee), H. F. Brown, F. W. Hillman, E. R. Lewis, W. S. Moore, G. B. Wall, Jr.

The subject assigned this committee is Tunnel Lighting. An investigation made to determine the distance in from the portals at which there is sufficient daylight to carry on work satisfactorily shows a considerable variation, but stated in general terms, the average distances are as follows:

Single-track tunnels on tangent ....200 ft.
Double-track tunnels on tangent ....300 ft.
Single-track tunnels on 10-deg. curve ....125 ft.

With other curves, the distances vary from 200 ft. on tangent to 125 ft. on 10-deg. curves.

There is also a considerable variation in this distance depending on the depths and widths of approach cuts, or whether or not the portals were shadowed by high mountains, on weather conditions, and the direction of the tunnel with respect to the relative position of the sun at the time the tests were made. No general definite distance can be laid down to cover individual cases.

Questionnaires were sent to 14 railroads, asking for information as to their present practice and for recommendations as to the type of artificial lighting that their experience would indicate as most suitable. Replies were received from all 14 roads, covering a total of 941 tunnels with an aggregate length of 196.54 miles. Included in their figures are 66 electrically lighted tunnels with a length of 50.52 miles. All except four of the roads have one or more tunnels electrically lighted, with permanent wiring circuits. One road with 30 tunnels, and a tunnel length of 8.34 miles, has electric wiring in all of them. Another road with 189 tunnels, having a length of 36.57 miles, has 14 tunnels with permanent wiring connected with an outside source of current. These tunnels are lighted during the passage of trains. Repair gangs working in other tunnels not connected with public service circuits are furnished with portable generating sets.

These generating sets are set up outside the portals and temporary wiring is installed inside the tunnel before starting any work.

There are many different types of wiring and lighting arrangements. Where permanent wiring circuits are installed, one road uses bare, hard-drawn, copper wire attached to the wall with metal brackets equipped with insulators. Portable lighting units are used which can be attached to these circuits at any point by means of clips.

Several roads use portable lighting units with provision for plugging them in at various distances throughout the tunnel. These portable lighting units in some instances have a single lamp, in others, a group of lamps. The current consumption varies from 100 to 500 watts. Other roads use lights in fixed locations, while some roads use both fixed lights and portable lighting units.

The circuits are of various types: Bare, open wire, waterproof and insulated wire of various kinds, and lead covered and other types of cable. Some wires and cables are laid in conduit, others in the open and attached to the side walls by means of various devices. Some circuits are lit by approaching trains, with a separate provision whereby the lights can also be switched on for workmen in the tunnel.

Five roads use small portable electric generating sets that can be moved to a tunnel when work is to be done, and then removed. One road has installed permanent wire circuits and another installs temporary wiring when work is to be done. In each case portable generating plants are set up outside tunnels and connected to these circuits. Other roads set up portable generating plants inside the tunnels, using rubber-covered cables.

Notwithstanding the wide variation in the methods employed in lighting tunnels, each road reports that its own individual method is satisfactory.

Of all the tunnels reported, there are 875, with a length of 146 miles, that are lighted by various means other than electric. These include ordinary hand lanterns, miners' head lamps, carbide lights, both small and of the flood type; open flares such as gasoline banjo torches, and gasoline lamps with mantles over the burners.

In reporting on the efficacy of lighting other than electric, one road with electric lighting in all its tunnels, and two roads that have no electric lighting, state that lighting other than electric is not satisfactory. Another comment is "Not entirely satisfactory". Two others gave somewhat qualified answers, i.e., "fairly satisfactory". One road did not answer this question. Seven others state that the type of lighting (not electric) which they are using is satisfactory.

The replies were almost unanimous that light units that can be moved around are better than lights in a fixed position. Where electric current is available at a reasonable cost, opinion is about equally divided as to whether or not permanent electric wiring circuits should be put in or the light supplied by portable electric generating plants that can be moved from tunnel to tunnel as required. Generally, electric light of some description is recommended, although two roads qualified their endorsement by limiting its consideration to special cases.

There is a great difference of opinion as to whether wiring should be what is known as the open or exposed type, or whether it should be conduit; also, as to the type or style of wire or cable to be used.

The recommendation as to minimum length of tunnel for which lighting should be considered varies from 300 to 1,200 ft.

Your committee considered the lighting question principally from the standpoint of providing light for carrying on tunnel repair work. The information supplied by various roads shows that many have lighting systems in some of their tunnels which are lit throughout during passage of trains. Lighting during passage of trains is effective for electrically-operated tunnels. In steam-operated tunnels the light is obliterated by smoke during the passage of trains, except on downgrades. The period of time the light is obliterated depends on the length of the tunnel, grade, curvature, atmospheric conditions, the number of engines handling the trains, and, if artificially ventilated, on the rate at which fresh air is supplied in relation to the total volume of air within tunnel.

This report is offered as information.

Appendix F

(8) Fences

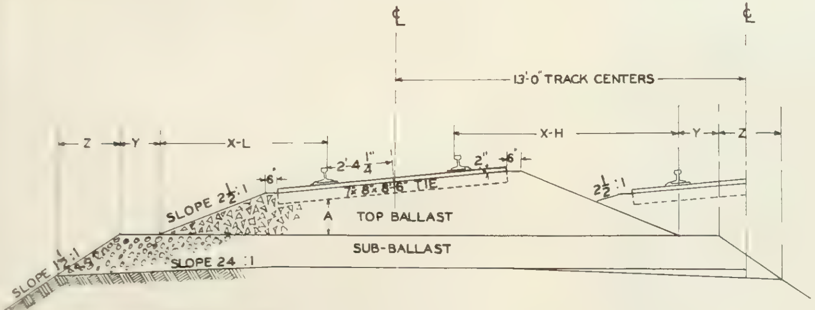
Corrosion-Resisting Fence Wire, Collaborating With Appropriate Subcommittees of Committee A-5 on Corrosion of Iron and Steel, ASTM

A. R. Jones (chairman subcommittee), F. W. Hillman, P. J. McCarthy, W. C. Pruett, P. H. Winchester, G. E. Yahn.

Your committee is collaborating with ASTM Committee A–5, which is conducting exposure tests of farm field fencing, unfabricated wire, wire strand and chain-link fencing in locations that are considered representative of atmospheric conditions encountered in the service use of these products. The object of these tests is to determine the rate of rusting and other depreciation in pure country air, sea coast air and smoky industrial atmospheres. There are 72 samples of farm and railroad wire fence, 21 samples of chain-link fence, 23 samples of barbed wire, 13 samples of wire strand and 120 samples of unfabricated wire of the kinds used in making the above finished products.

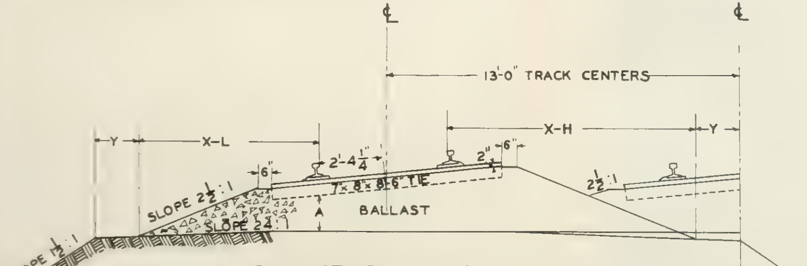
Portions of these samples are placed at 11 locations extending from Bridgeport, Conn. to Santa Cruz, Cal. The wires range from No. 6 to No. 14½ gage, five gages in all. The weights of the coating range from 0.25 to 0.30 ounces per square foot of surface. There are also bare wires and copper clad, as well as lead-clad wires and stainless steel.

1. DEP
2. UND
3. ROA
4. QUA
5. VAR



BALLAST SECTION No 3 - CURVES

MATERIALS: PREPARED GRAVEL, 0 TO 20% CRUSHED PARTICLES AND PIT RUN GRAVEL.



BALLAST SECTION No 4 - CURVES

MATERIALS: PREPARED GRAVEL, 0 TO 20% CRUSHED PARTICLES AND PIT RUN GRAVEL.

TABLE OF VARIABLES AND QUANTITIES PER 100 FEET SINGLE TRACK-FOR SECTION No 3-CURVES.

SECTION ✳	A	SUPERELEVATION 1" X-L	1" X-H	1" CU.YDS.	2" X-L	2" X-H	2" CU.YDS.	3" X-L	3" X-H	3" CU.YDS.	4" X-L	4" X-H	4" CU.YDS.	5" X-L	5" X-H	5" CU.YDS.	6" X-L	6" X-H	6" CU.YDS.
3-a-b	16"	6'-8"	7'-1"	100	6'-7"	7'-4"	104	6'-6"	7'-8"	108	6'-5"	7'-11"	111	6'-4"	8'-3"	115	6'-3"	8'-6"	118
3-c-d-e-f	14"	6'-3"	6'-8"	88	6'-2"	6'-11"	91	6'-1"	7'-3"	94	6'-0"	7'-6"	99	5'-11"	7'-10"	103	5'-10"	8'-1"	107
3-g-i	12"	5'-10"	6'-3"	75	5'-9"	6'-6"	78	5'-8"	6'-10"	82	5'-7"	7'-1"	85	5'-6"	7'-5"	89	5'-5"	7'-8"	93
3-h-j-k-n	10"	5'-5"	5'-10"	65	5'-4"	6'-1"	68	5'-3"	6'-5"	71	5'-2"	6'-8"	74	5'-1"	7'-0"	77	5'-0"	7'-3"	81
3-l-o	8"	5'-0"	5'-5"	53	4'-11"	5'-8"	56	4'-10"	6'-0"	59	4'-9"	6'-3"	63	4'-8"	6'-7"	66	4'-7"	6'-10"	69
3-m-p	6"	4'-7"	5'-0"	42	4'-6"	5'-3"	45	4'-5"	5'-7"	48	4'-4"	5'-10"	50	4'-3"	6'-2"	54	4'-2"	6'-5"	57

TABLE OF VARIABLES AND QUANTITIES PER 100 FEET SINGLE TRACK-FOR SECTION No 4-CURVES.

SECTION ✳	A	SUPERELEVATION 1" X-L	1" X-H	1" CU.YDS.	2" X-L	2" X-H	2" CU.YDS.	3" X-L	3" X-H	3" CU.YDS.	4" X-L	4" X-H	4" CU.YDS.	5" X-L	5" X-H	5" CU.YDS.	6" X-L	6" X-H	6" CU.YDS.
4-a	24"	9'-0"	9'-6"	165	8'-11"	9'-9"	168	8'-10"	10'-1"	172	8'-9"	10'-5"	179	8'-8"	10'-9"	184	8'-7"	11'-1"	189
4-b	22"	8'-7"	9'-0"	150	8'-6"	9'-4"	154	8'-5"	9'-8"	158	8'-4"	10'-0"	163	8'-3"	10'-4"	167	8'-1"	10'-8"	172
4-c	20"	8'-1"	8'-6"	134	8'-0"	8'-10"	138	7'-11"	9'-2"	142	7'-10"	9'-6"	146	7'-9"	9'-10"	151	7'-8"	10'-2"	156
4-d-e	18"	7'-8"	8'-1"	119	7'-7"	8'-5"	123	7'-6"	8'-9"	128	7'-4"	9'-1"	131	7'-3"	9'-4"	135	7'-2"	9'-8"	140
4-f	16"	7'-2"	7'-7"	105	7'-1"	7'-11"	108	7'-0"	8'-3"	112	6'-11"	8'-7"	116	6'-10"	8'-11"	120	6'-9"	9'-3"	125
4-g-h	14"	6'-9"	7'-2"	92	6'-8"	7'-6"	96	6'-6"	7'-9"	98	6'-5"	8'-1"	102	6'-4"	8'-5"	107	6'-3"	8'-9"	110
4-i	12"	6'-3"	6'-8"	78	6'-2"	7'-0"	82	6'-0"	7'-4"	85	5'-11"	7'-8"	89	5'-10"	8'-0"	93	5'-9"	8'-4"	97
4-j-k	10"	5'-9"	6'-2"	66	5'-8"	6'-6"	69	5'-7"	6'-10"	73	5'-6"	7'-2"	77	5'-5"	7'-6"	80	5'-4"	7'-10"	84
4-e	8"	5'-4"	5'-9"	55	5'-3"	6'-1"	58	5'-2"	6'-5"	61	5'-1"	6'-9"	65	4'-11"	7'-1"	68	4'-10"	7'-4"	71
4-m	6"	4'-10"	5'-3"	45	4'-9"	5'-7"	49	4'-8"	5'-11"	51	4'-7"	6'-3"	53	4'-6"	6'-7"	56	4'-5"	6'-11"	60

✳ SUB. LETTERS GIVEN IN SECTION COLUMN INDICATE CORRESPONDING SECTIONS FOR TANGENT TRACK; SEE MANUAL PAGE No. 2-18.

NOTES

1. DEPTH OF SECTION TO USE WILL DEPEND ON CONDITIONS PECULIAR TO EACH RAILROAD OR LOCATION.
2. UNDER CERTAIN CONDITIONS IT MAY BE NECESSARY TO USE A DEPTH IN EXCESS OF MAXIMUM SHOWN IN TABLES.
3. ROADBED TO BE WIDENED ON HIGH SIDE WHEN NECESSARY TO PROVIDE MINIMUM OF 18 INCHES FOR Y.
4. QUANTITIES COMPUTED ON BASIS OF 3200 TIES PER MILE AND 15% ALLOWANCE FOR SHRINKAGE.
5. VARIABLES AND QUANTITIES FOR SUPERELEVATION OVER 3 INCHES ARE SHOWN AS INFORMATION.

A.R.E.A.
BALLAST SECTIONS
SINGLE AND MULTIPLE TRACK-CURVES
(FOR SUPERELEVATIONS UP TO AND INCLUDING 3 INCHES)

At the outset of the tests the wires were all tested at the National Bureau of Standards, Washington, D. C., for composition of base metal, weight of coating and tensile strength. Of the unfabricated wires there are seven sets at each location. Periodically some of them will be taken down and tested in tension to determine the depreciation by the loss in strength. Some are also being tested periodically for loss in weight of the zinc coating. The fabricated material as well as the plain wire is periodically inspected for appearance and progress of rust. The plan of this test was published in the Proceedings of the ASTM, Vol. 34, Part 1, page 159 (1934) and in Part 1 of Proceedings of 1937 pages 122–150.

Shipment of samples to the test fields was completed in October, 1936. Erection was completed and the exposure begun at the 11 sites between October, 1936 and June. 1937. Field inspections, begun in 1937, are made twice each year by a traveling committee at the test sites at Bridgeport, Sandy Hook, N. J., Pittsburgh, Pa., and State College. Field inspections at the other seven sites are made only once a year by local engineers in charge of the respective local testing field.

The first report on the inspection of the exposed samples will appear in the ASTM Proceedings of 1939, report of Committee V on Field Tests of Metallic Coatings.

The report is presented as information with the recommendation that the subject be continued.

Appendix G

(10-a) Ballast Section Design

A. D. Kennedy (chairman, subcommittee), A. P. Crosley, R. L. Dyke, F. L. Guy, T. P. Polson, G. B. Wall, Jr.

The committee has prepared two ballast section plans designed for curves: Section No. 3, Curves, and No. 4, Curves, for prepared gravel under 20 percent crushed particles and for pit run gravel.

These sections are recommended for super-elevations up to and including three inches, and are presented for acceptance and inclusion in the Manual.

Appendix H

(10-c) Investigate the Use of Asphalt in Ballast

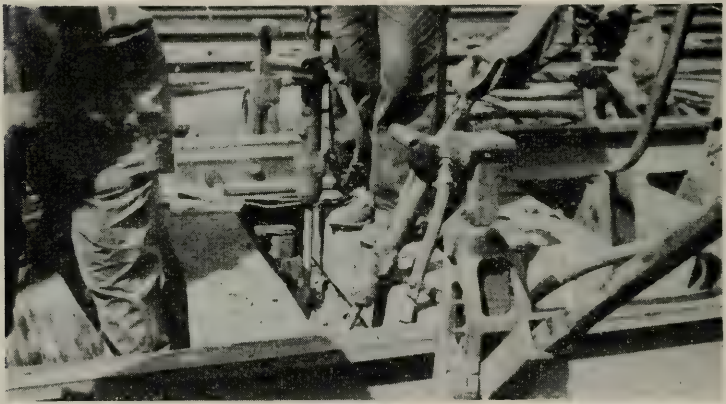
J. M. Podmore (chairman, subcommittee), J. A. Given, P. J. McCarthy, J. A. Noble, Stanton Walker, C. S. Wicker.

Emulsified Asphalt Ballasted Track

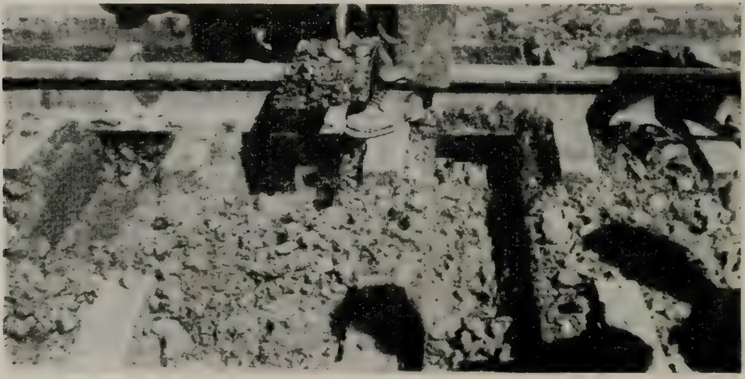
On the New York Central Railroad a test section 600 ft. long was installed in the eastbound high speed track at Bryan, Ohio, station platform in the fall of 1939. At this location the track is on a long tangent and a 0.2 percent down grade in favor of the traffic. On account of traffic conditions it was not possible to take the track out of service during the progress of the work. The speed allowed passenger trains on this section of track is 80 miles per hour. The track was prepared for the emulsified asphalt-coated ballast in the following manner:

First, the crossties were all renewed with twenty-four 7-in. by 9-in. by 8-ft. 6-in. sawed creosoted ties to the 39-ft. rail; new double-shoulder tie plates were applied to all ties. Then new over-sized crowned toeless 36-in. six-hole bars were put on Dudley section

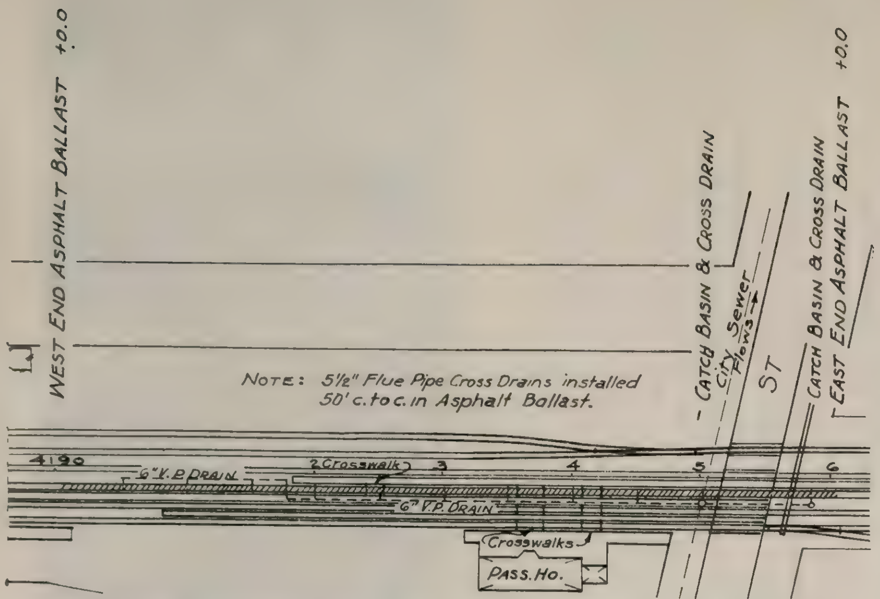
View of the Track Before it Was Reconditioned.



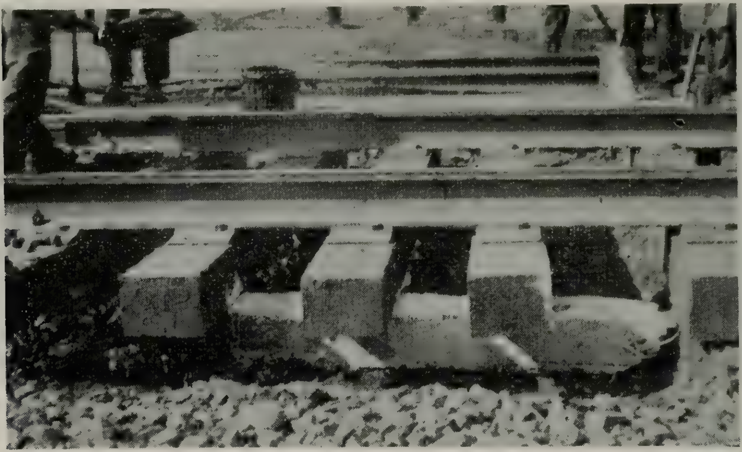
Breaking Up the Cemented Ballast.



Removing the Old Ballast.


WEST END ASPHALT BALLAST +0.0
CATCH BASIN & CROSS DRAIN
City Sewer
Flows
ST
CATCH BASIN & CROSS DRAIN
EAST END ASPHALT BALLAST +0.0
NOTE: 5½" Flue Pipe Cross Drains installed 50' c. to c. in Asphalt Ballast.
4190
2 Crosswalk
3
4
5
6
6" V.P. DRAIN
6" V.P. DRAIN
Crosswalks
PASS. HO.

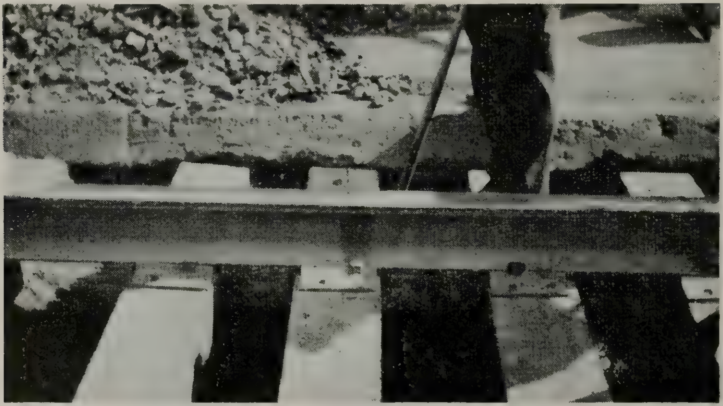
Above—The Hatched Lines Indicate the Location of the Test Section.
Right—Perforated Boiler Flues Were Used as Drains.



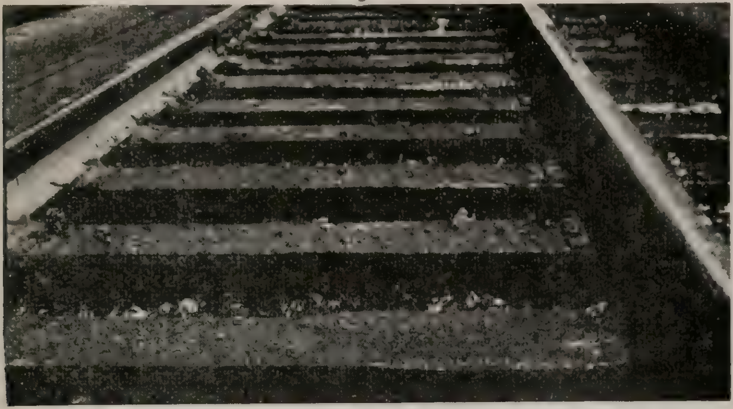
The Ties Were Placed on Skids.

127-lb. rail (laid new in 1927), which was put in good surface condition by grinding the rail heads at the joints where necessary.

The old ballast was removed for the full width between the platforms—about 9-ft. 9-in.—and below the bottom of the ties to a depth of 8 in. As the old ballast under the ties was almost like cement, it was necessary to break it up and loosen it so it could be easily shoveled out. Air tampers with a chisel-shaped face were used. At the start of the work, about five feet of the track was dug out to a depth of eight inches below the bottom of the ties and skids made by sawing an old tie in two at the center were placed under the ties directly under each rail. This permitted the track to be kept in service for all trains with a slow order of 30 miles per hour, which was kept on continuously until the emulsified asphalt-coated stone ballast was put in place under all the ties.



Ties Resting on the Emulsified Asphalt Ballast.



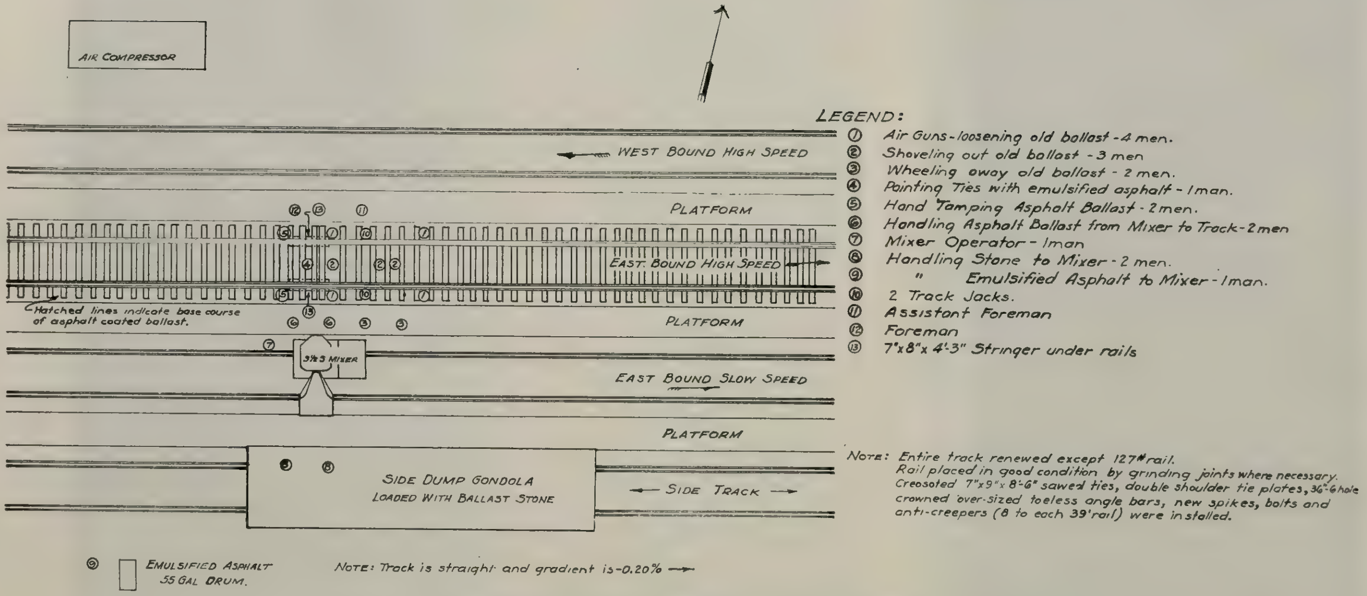
A Close-Up of the Track After the Ties Were Coated, Preparatory to Placing the Seal Coat.

To facilitate easy moving of the skids as the old ballast was removed, track jacks were used to hold up the track while the skids were moved forward. As fast as the old ballast was removed the emulsified asphalt-coated stone ballast was placed back of the skids up to the bottom of the ties. Line and grade were set with engineers' instruments for the correct alinement and lift. The emulsified asphalt-coated ballast was tamped with air tampers as fast as it was placed under the ties.

An interval of about two weeks elapsed between the first and the final lift. The final lift was a surface lift to true up the grade and eliminate any irregularities due to settlement after the first lift. The rail anchors, eight to a rail, were replaced.

Cross drains were installed after the final lift. They consisted of old flue pipe 5½ in. in diameter with locomotive boiler netting welded to the ends and over inlets near the

General View of the Reconditioned Track.

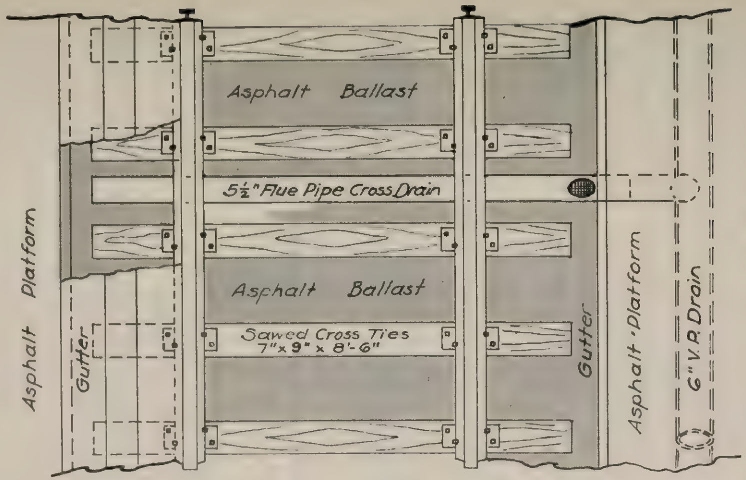


LEGEND:
① Air Guns-loosening old ballast-4 men.
② Shoveling out old ballast-3 men
③ Wheeling away old ballast-2 men.
④ Pointing Ties with emulsified asphalt-1 man.
⑤ Hand Tamping Asphalt Ballast-2 men.
⑥ Handling Asphalt Ballast from Mixer to Track-2 men
⑦ Mixer Operator-1 man
⑧ Handling Stone to Mixer-2 men.
⑨ " Emulsified Asphalt to Mixer-1 man.
⑩ 2 Track Jacks.
⑪ Assistant Foreman
⑫ Foreman
⑬ 7"x8"x 4'-3" Stringer under rails

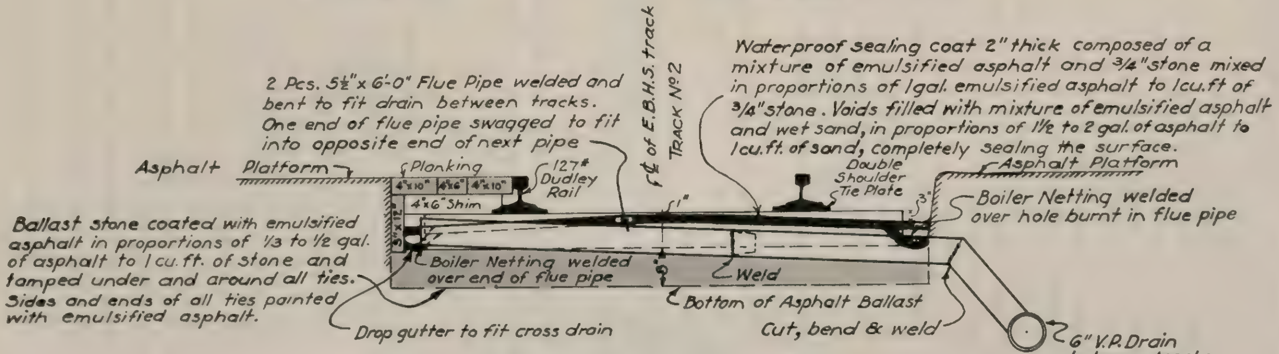
NOTE: Entire track renewed except 127# rail.
Rail placed in good condition by grinding joints where necessary.
Creosoted 7"x9"x 8'-6" sawed ties, double shoulder tie plates, 36"-6 hole crowned over-sized toeless angle bars, new spikes, bolts and anti-creepers (8 to each 39' rail) were installed.

NOTE: Track is straight and gradient is -0.20% →

Organization Used in Installing the Base Course.



Plan and Cross-Section Showing Details of Construction.


2 Pcs. 5½"x 6'-0" Flue Pipe welded and bent to fit drain between tracks. One end of flue pipe swagged to fit into opposite end of next pipe
℄ of E.B.H.S. track
TRACK Nº 2
Waterproof sealing coat 2" thick composed of a mixture of emulsified asphalt and ¾" stone mixed in proportions of 1 gal. emulsified asphalt to 1 cu. ft of ¾" stone. Voids filled with mixture of emulsified asphalt and wet sand, in proportions of 1½ to 2 gal. of asphalt to 1 cu. ft. of sand, completely sealing the surface.
Asphalt Platform
Planking
4"x10"
4"x6"
4"x10"
127# Dudley Rail
4"x6" Shim
1"
Double Shoulder Tie Plate
Asphalt Platform
3"
Boiler Netting welded over hole burnt in flue pipe
Ballast stone coated with emulsified asphalt in proportions of ⅓ to ½ gal. of asphalt to 1 cu. ft. of stone and tamped under and around all ties. Sides and ends of all ties painted with emulsified asphalt.
Boiler Netting welded over end of flue pipe
Weld
Bottom of Asphalt Ballast
Drop gutter to fit cross drain
Cut, bend & weld
6" V.P. Drain between tracks

SECTION AT CROSS DRAIN

elbow where the pipe is bent down into the longitudinal drain between tracks. The old flue pipe was originally swaged and it was an easy matter to weld them together to give the desired length. The drain between tracks was installed years ago and the cross drains were connected into this drain.

Before the seal coat was applied the ties were coated with emulsified asphalt on the sides and ends to provide a better bond. Then the same mixture used in the base course was put compactly between the ties and brought to the proper height. On top of this a seal coat two inches deep made of a mixture of ¾-in. stone and emulsified asphalt was tamped into the ballast. On top of the ¾-in. stone sharp wet sand, thoroughly mixed with emulsified asphalt, was broomed into the voids. The finished surface is about one inch below the top of the ties at the center of the track and slopes to about three inches below the top of the ties at the ends. Gutters were formed at the ends of the ties to carry the surface water to the drains. In constructing the test section of asphalt ballasted track, 3,960 gal. of emulsified asphalt were used, or 6.6 gal. per foot of track. Ties sawed four sides were used to afford better bond with the emulsified asphalt mixture than could be secured with hewed ties or ties sawed only on the top and bottom.

The photographic views illustrate the condition of the track before the work on this project was started, and the methods of performing the work. Four drawings show the location, the detail of construction and the plan of organization for the conduct of the work.

The location selected for this test favored the conduct of the work. Cars loaded with stone and sand could be set out on a siding and moved along the track as the work progressed.

The specifications for the manufacture of the emulsified asphalt, the proportions to be used in the stone and sand, and the method of application are given in the report appearing in the Proceedings for 1939, pages 540–542.

This report is presented as information with the recommendation that the subject be continued.

Appendix I

(12) Revision of Manual

A. E. Botts (chairman, subcommittee), A. D. Kennedy, F. W. Alexander, Paul Chipman, L. J. Drumeller, A. T. Goldbeck, A. R. Jones, H. W. Legro, J. M. Podmore, C. S. Robinson, L. S. Rose, W. C. Swartout, H. M. Swope.

The committee recommends the following revision on page 1–31 of the Manual:

Under 401–C, Specifications, Section 33, Formation of Layers,—change the word "feet" in the second line to "inches".

The reason for the change is to conform to modern grading practice, in which layers of more than 12 inches in thickness are seldom used, and where a less thickness is frequently specified.

In Section 34, Rolling, omit the word "Self-propelled".

The reason for this change is to permit the use of a sheep's foot or other roller drawn by a tractor.

Report of Committee 5—Track

W. G. Arn, *Chairman,*
Lem Adams
L. L. Adams
C. W. Baldridge
A. L. Bartlett
W. H. Bettis
W. H. B. Bevan
F. J. Bishop
L. H. Bond
R. W. E. Bowler
C. W. Breed
E. W. Caruthers
A. Chinn
H. R. Clarke
O. U. Cook
E. D. Cowlin
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L. W. Deslauriers
J. A. Ellis
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F. S. Hales
H. H. Harman
N. M. Hench
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E. T. Howson
A. F. Huber
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S. N. Mills
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A. E. Perlman, *Vice-Chairman,*
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J. A. Reed
O. C. Rehfuss
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W. L. Roller
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G. L. G. Smith
G. M. Strachan
C. R. Strattman
J. N. Todd
H. von Schrenk
H. N. West
R. P. Winton
J. G. Wishart
M. J. T. Zeeman
Committee.

To the American Railway Engineering Association:

Your committee respectfully presents reports on the subjects assigned, as follows:

1-G. Revision of Manual—General—(Appendix A). It is recommended that the revisions shown herein be adopted and printed in the Manual.

1-S. Revision of Manual—String Lining of Curves (Appendix B). It is recommended that the revisions shown herein be adopted and printed in the Manual.

2. Fastenings for continuous welding of rail, collaborating with Committee 4—Rail (Appendix C). The report on this subject is offered as information.

3. Plans and specifications for track tools, collaborating with Committee I—Roadway and Ballast, and with Committee 22—Economics of Railway Labor (Appendix D). It is recommended that revised plans 20A, 27, 28, 29 and 30 be adopted and printed in the Manual; that Plan 8-40, timbers tongs, submitted as information last year as Plan 8-A, be adopted and printed in the Manual and Plan 8 withdrawn and that the physical test for timber tongs be adopted and printed in the Manual.

4. Plans for switches, frogs, crossings, spring and slip switches, collaborating with the Signal section, and track construction in paved streets, collaborating with Committee 9—Highways, on matters pertaining to track construction in paved streets (Appendix E). It is recommended that the plans listed for adoption, be adopted and printed in the portfolio, and that the superseded and obsolete plans listed be withdawn.

5. Corrosion of rail and fastenings in tunnels, collaborating with Committee 4—Rail (Appendix F). The report on this subject is offered as information.

6. Design of tie plates for RE rail sections as developed, collaborating with Committee 3—Ties and Committee 4—Rail (Appendix G). It is recommended that the specifications for hot worked, high-carbon steel tie plates be adopted and printed in the Manual.

7. Practicability of using reflex units for switch lamps and targets, collaborating with Committee 10—Signals and Interlocking. Progress in study—no report.

Bulletin 416, February, 1940.

8. Welding of manganese castings in special trackwork, collaborating with Committee 27—Maintenance of Way Work Equipment (Appendix H). The report on this subject is offered as information.

9. Bolt tension necessary for proper supporting of joints (Appendix I). The report on this subject is offered as information.

10. Lubrication of rail on curves, collaborating with Committee 16—Economics of Railway Location and Operation. Progress in study—no report.

11. Prevention of damage due to brine drippings on track structures, collaborating with Mechanical division (Appendix J). The report on this subject is offered as information.

12. Specifications for laying rails, designed to set up the requirements for good workmanship (Appendix K). The report on this subject is offered as information.

13. Methods of shimming track. Progress in study—no report.

14. Spirals for high speed operation, collaborating with Committee 16—Economics of Railway Location and Operation (Appendix L). It is recommended that the revisions shown herein be adopted and printed in the Manual.

THE COMMITTEE ON TRACK,
W. G. ARN, *Chairman.*

Appendix A

(1–G) Revision of Manual

M. J. T. Zeeman (chairman, subcommittee), L. L. Adams, W. H. B. Bevan, C. W. Breed, J. A. Ellis, F. W. Hillman, E. T. Howson, A. A. Johnson, J. de N. Macomb, S. N. Mills, J. B. Myers, I. H. Schram, G. L. G. Smith, J. G. Wishart.

The committee submits the following revisions:

Page 5–18

Under "Specifications for the laying of new track" delete reference to the 1923 Proceedings, and insert the specifications now shown in the 1929 Manual, pages 259–262.

Delete heading and text on "Canting Rail".

Page 5–33

Delete all matter now shown on this page.

Page 5–34

Delete the text from top of page down to subheading "3. Permanent Monuments." In lieu of subheading "3. Permanent Monuments" insert main heading—

Permanent Monuments

retaining the text as now shown.

Page 5–42

Delete heading of "Maintenance of Surface" and substitute therefor "Elevations and speeds for Curves," retaining all data now shown on this page, except delete "1", ahead of "Elevation of Curves".

Ahead of the last paragraph as now shown on this page, insert the following:

The operation of passenger trains at speeds of approximately 100 miles per hour warrants a careful study of curvature, including the amount of elevation and the condition of transition between tangents and curve and between compound curves.

ELEVATIONS AND SPEEDS FOR CURVES

S_E = Speed at equilibrium elevation, in miles per hour.
S_P = Speed at 3" unbalanced elevation, in miles per hour.

CURVES	ELEVATIONS	¼"	½"	¾"	1"	1¼"	1½"	1¾"	2"	2¼"	2½"	2¾"	3"	3¼"	3½"	3¾"	4"	4¼"	4½"	4¾"	5"	5¼"	5½"	5¾"	6"	6¼"	6½"	6¾"	7"	ELEVATIONS	CURVES
0° 30'	S_E	30	40	50	55	60	65	70	75	80	85	90	95	100		105	110													S_E	0° 30'
	S_P	100		105	110																									S_P	
1° 00'	S_E	20	25	35		40	45	50	55		60	65		70		75		80		85			90		95			100		S_E	1° 00'
	S_P	70		75		80		85			90		95			100		105			110									S_P	
1° 30'	S_E			25	30	35		40	45		50		55			60		65			70			75			80			S_E	1° 30'
	S_P	55		60		65			70			75			80			85			90				95				100	S_P	
2° 00'	S_E		20		25	30		35		40		45		50			55			60			65				70			S_E	2° 00'
	S_P	50			55			60			65				70				75				80				85			S_P	
2° 30'	S_E						30			35		40			45			50			55				60					S_E	2° 30'
	S_P	45				50			55				60				65					70								S_P	
3° 00'	S_E			20		25		30			35			40			45				50				55					S_E	3° 00'
	S_P	40			45				50				55					60					65					70		S_P	
3° 30'	S_E						25			30			35			40				45				50						S_E	3° 30'
	S_P			40				45					50				55							60						S_P	
4° 00'	S_E				20			25			30			35				40					45					50		S_E	4° 00'
	S_P	35				40					45					50					55						60			S_P	
4° 30'	S_E											30				35				40					45					S_E	4° 30'
	S_P			35				40						45					50						55					S_P	
5° 00'	S_E					20			25				30				35					40						45		S_E	5° 00'
	S_P				35					40						45						50							55	S_P	
5° 30'	S_E						20			25				30					35					40						S_E	5° 30'
	S_P						35						40						45						50					S_P	
6° 00'	S_E							20			25				30						35					40				S_E	6° 00'
	S_P	30							35						40						45								50	S_P	
7° 00'	S_E								20				25					30						35						S_E	7° 00'
	S_P					30						35							40								45			S_P	
8° 00'	S_E									20				25						30							35			S_E	8° 00'
	S_P	25						30							35								40							S_P	
9° 00'	S_E										20					25							30							S_E	9° 00'
	S_P			25							30							35									40			S_P	
10° 00'	S_E											20						25							30					S_E	10° 00'
	S_P					25							30									35								S_P	
11° 00'	S_E												20						25								30			S_E	11° 00'
	S_P						25								30										35					S_P	
12° 00'	S_E												20								25									S_E	12° 00'
	S_P	20							25									30										35		S_P	

Table 507—Proposed.

Equilibrium speed on an elevated curve is the speed at which the resultant of forces passes midway between the rails, and the lateral pressure against the rails is zero. If it were possible to operate all classes of traffic at the same speed around a curve, the ideal condition of smooth riding and minimum rail wear could be obtained by elevating for equilibrium. However, a section of curve track must usually handle several classes of traffic operating at different speeds. A slow train passing over a curve that is elevated for a much higher speed tends to throw the track out of surface and to cause excessive wear on the inside rail.

Safety and comfort limit the speed at which a passenger train may negotiate a curve. Any speed that gives comfortable riding on a curve is well within the limits of safety. Experience has shown that the usual passenger coach, pullman car or light-weight equipment will ride comfortably around a curve at a speed which would require an elevation about three inches higher for equilibrium. As far as high speed traffic is concerned, it may therefore be said that passenger comfort governs train speed on curves and that trains may be operated over curves at speeds somewhat greater than equilibrium speed. Advantage is taken of this condition in operating high-speed trains on track that must also carry slower traffic.

Since the elevation required is a function of the train speed, this speed is the first element to be determined.

Ordinarily an elevation of 6 inches should not be exceeded for a track carrying both fast and slow traffic; and an elevation of 7 inches where one class of traffic is carried exclusively.

The inner rail should preferably be maintained at grade.

Page 5–43

Table 507. Change heading from "Speeds of trains through Curves" to "Elevations and Speeds for Curves." Delete the table in its entirety and replace it with the table marked "Table 507—Proposed," appearing in this report.

Page 5–44

Delete the six paragraphs at top of this page, down to "2. Vertical curves."

Delete "2. Vertical Curves," and insert main heading "Vertical Curves," retaining text, as now shown.

Page 5–46

Delete heading "Maintenance of Gage," also subheading and text for paragraph numbered 1.

Delete subheading "2. General" and insert heading "Gage", retaining the text as now shown.

Delete the note referring to the Portfolio of Trackwork plans for data on gages and flangeways, at bottom of page.

In Glossary, page 44:

Delete "Spur" and its definition.

Appendix B

(1–S) Revision of Manual—String Lining of Curves

C. R. Strattman (chairman, subcommittee), L. L. Adams, C. W. Baldridge, L. H. Bond, H. R. Clarke, E. T. Howson, S. H. Poore.

The committee recommends revision in that portion of Manual dealing with string lining of curves by chord method pages 5–36 to 5–41, inclusive.

1. That the heading be revised to read as follows:

   String Lining of Curves by the Chord Method*.

2. Addition of foot note to heading as follows:

   * For more detailed information see pages 493 to 508 inclusive, 1933 Proceedings.

3. Insert a sentence at end of first sentence, paragraph one, page 5–36, as follows:

   The method outlined below is confined to curves in which the angle between tangents is unchanged.

4. Revise paragraph 6, page 5–36, by adding to the last sentence the following, "and the sum of the mid-ordinates of the realined curve must equal the sum of the original measured mid-ordinates".
5. Omit paragraph 7, page 5–36, reading, On most curves, etc.
6. Revise paragraph 6, page 5–37, to read as follows:

   Column 4, headed Difference, shows the difference between the ordinates in columns 2 and 3.

7. Revise paragraph 8, page 5–37, to read as follows:

   Column 7 is for the full throw which is double the figure shown in column 6. Negative throw indicates that the track at that station is to be thrown in, while positive throw indicates that the track is to be thrown out.

8. Revise paragraph 9, page 5–37, to read as follows:

   Column 8 is obtained by subtracting algebraically the full throw from one-half the gage, 28.25 in.

9. Revise paragraph 12, page 5–37, to read as follows:

   In the example in Table 502 the end of the east spiral is taken at Station 7, while the end of the west spiral is taken at Station 24.

10. Omit material beginning with the second paragraph from the bottom of page 5–37, reading, "In the first trial of computations," etc., and continuing through page 5–41, and substitute the following:

    In the example, computations based on selected revised spiral ordinates in sub-column A Table 502, carried through to Column 6, indicate a half-throw of 31 or a full-throw of 6.2 in. at Station 7, which is too great. The minus sign of the half-throw indicates that ordinates slightly smaller should be selected. Slightly smaller spiral ordinates are therefore entered in sub-column B and the curve ordinate of 45 is carried out through Station 11. This gives too great a throw in the positive direction.

    Therefore, interpolate a spiral between those used in sub-columns A and B, and enter these new spiral ordinates in sub-column C. The curve ordinate of 46 is carried out a few stations below the S.C. (spiral curve) at Station 7. Computing a third time through to column 6, the half-throw at Station 7 is —26 and at Station 11 is —10 which gives a practical throw. For trial the circular curve ordinate of 46 in Column 3 is carried through to Station 23 (one station back on the circular curve from the C.S. (curve spiral) and extension made to Column 6, where the half throw is +31.

Sum up in Column 2 the measured ordinates from Stations 24 to 32 inclusive in the original spiral, which total 190. The sum of the measured ordinates from Stations 0 to 23 inclusive is 922, bringing the total sum of measured ordinates to 1,112. The sum of the revised ordinates from Stations 0 to 23 inclusive is 921. To assure that Column 5 will end in 0, the sum of the revised spiral ordinates from stations 24 to 32 inclusive must equal 191. Such revised spiral ordinates are entered in sub-column "C".

Carrying the calculations through to Column 6, the sum of differences check out 0, but the final half-throw is +17, indicating that the trial spiral ends in a parallel tangent. To end in the original tangent, both Columns 5 and 6 must balance; therefore, an adjustment of the revised ordinates is necessary and is made according to the following rule.

STATIONING FROM EAST TO WEST
TABLE 502

	Station Numbers	Ordinates					Difference				Sum of Differences Up to and including the Sta.				Half Throw Sum Col. 5 up to and including Preceding Sta.				Full Throw	Gage to Tack	Remarks
		Measured	Revised				Col. 2 - Col. 3														
	1	2	3				4				5				6				7	8	9
			A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D			
	-1	0	0	0	0		0	0	0		0	0	0		0	0	0		0	28.25	
T.S.	0	1	1	1	1		0	0	0		0	0	0		0	0	0		0	28.25	
	1	5	7	6	7		-2	-1	-2		-2	-1	-2		0	0	0		0	28.25	
	2	14	13	13	13		+1	+1	+1		-1	0	-1		-2	-1	-2		-4	28.65	
	3	16	20	19	20		-4	-3	-4		-5	-3	-5		-3	-1	-3		-.6	28.85	
	4	26	27	26	26		-1	0	0		-6	-3	-5		-8	-4	-8		-1.6	29.85	
	5	30	34	32	33		-4	-2	-3		-10	-5	-8		-14	-7	-13		-2.6	30.35	
	6	43	40	39	40		+3	+4	+3		-7	-1	-5		-24	-12	-21		-4.2	32.45	
S.C.	7	56	46	44	45		+10	+12	+11		+3	+11	+6		-31	-13	-26		-5.2	33.45	
	8	49	47	45	46		+2	+4	+3		+5	+15	+9			-2	-20		-4.0	32.25	
	9	35	47	45	46		-12	-10	-11		-7	+5	-2			+13	-11		-2.2	30.45	
	10	51	47	45	46		+4	+6	+5		-3	+11	+3			+18	-13		-2.6	30.85	
	11	49	47	45	46		+2	+4	+3		-1	+15	+6			+29	-10		-2.0	30.25	
	12	43			46				-3				+3			+44	-4		-.8	29.05	
	13	45			46				-1				+2				-1		-.2	28.45	
	14	50			46	47			+4	+3			+6	+5			+1	+1	+.2	28.05	
	15	49			46				+3				+9	+8			+7	+6	+1.2	27.05	
	16	43			46				-3				+6	+5			+16	+14	+2.8	25.45	
	17	38			46				-8				-2	-3			+22	+19	+3.8	24.45	
	18	50			46				+4				+2	+1			+20	+16	+3.2	25.05	
	19	55			46				+9				+11	+10			+22	+17	+3.4	24.85	
	20	33			46				-13				-2	-3			+33	+27	+5.4	22.85	
	21	44			46				-2				-4	-5			+31	+24	+4.8	23.45	
	22	50			46	47			+4	+3			0	-2			+27	+19	+3.8	24.45	
	23	47			46				+1				+1	-1			+27	+17	+3.4	24.85	
C.S.	24	48			47	46			+1	+2			+2	+1			+28	+16	+3.2	25.05	
	25	38			41				-3				-1	-2			+30	+17	+3.4	24.85	
	26	37			34				+3				+2	+1			+29	+15	+3.0	25.25	
	27	21.			27				-6				-4	-5			+31	+16	+3.2	25.05	
	28	18			20				-2				-6	-7			+27	+11	+2.2	26.05	
	29	17			14	13			+3	+4			-3	-3			+21	+4	+.8	27.45	
	30	9			7				+2				-1	-1			+18	+1	+.2	28.05	
S.T.	31	2			1				+1				0	0			+17	0	0	28.25	
	32	0			0				0				0	0			+17	0	0	28.25	
	Sum	1112				1112															

Table 502.

When the final half-throw is positive, subtract from the revised ordinates having high station numbers and add an equal amount to the ordinates having low station numbers, choosing stations in pairs such that the sum of the differences of station numbers, taken in pairs, equals the numerical amount of the final half-throw. When the final half-throw is negative, reverse the procedure, subtracting from the ordinates having low station numbers and adding to those having high station numbers.

Since in Table 502 the final half-throw is +17, an ordinate (or ordinates) of a low station number will have to be increased and that of a high station number decreased. As it is desirable to keep the spiral uniform, let us change Station 24 from 47 to 46 and Station 22 from 46 to 47. This change will decrease the final half-throw by 2 or 1 × (Sta. 24—Sta. 22). Let us now change Station 29 from ordinate 14 to ordinate 13. Then following the rule, subtract (17 — 2 = 15) from Station 29, leaving 14 and increase the ordinate at Station 14 from 46 to 47. Enter these revised ordinates in sub-column "D", carrying out these computations again to Column 6, the final half-throw becomes 0 and the ordinates are balanced.

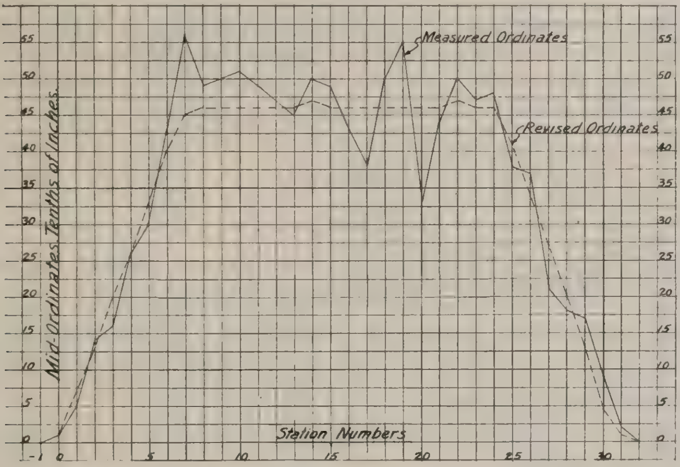


Fig. 512.

Computations are simplified by treating the entries in Columns 2, 3, 4, 5 and 6 as whole numbers, and placing decimal points in Column 7, as shown in Table 502.

In working out string lining problems considerable assistance can be gained by platting the measured mid-ordinates against the station numbers. Figure 512 shows the results for the curve given in Table 502. By platting the mid-ordinates in this manner, the ends of the spiral, as well as points of compounding, can be determined readily and an estimate of the average ordinate to use on the circular curve section can be closely determined.

When tabulations are completed and the curve staked, a copy of the form should be given the track foreman to enable him to apply the proper superelevation at the various stations as the track is lined.

Appendix C

(2) Fastenings for Continuous Welding of Rail

Collaborating with Committee 4—Rail

G. M. Magee (chairman, subcommittee), Lem Adams, L. L. Adams, C. W. Baldridge, A. L. Bartlett, W. H. B. Bevan, F. J. Bishop. O. U. Cook, E. D. Cowlin, J. A. Ellis, H. F. Fifield, F. S. Hales, H. H. Harman, N. M. Hench, E. T. Howson, J. de N. Macomb, W. A. Murray, J. B. Myers, J. A. Reed, G. J. Slibeck, C. R. Strattman, R. P. Winton.

The work of the subcommittee on this assignment has consisted of inspections of continuous welded rail installations secured with various types of fastenings followed by periodical reports on the service performance. No inspections were made during 1939 and no service report is given this year, since last year's report included all installations studied. It is hoped to make an inspection and service report next year.

Appendix D

(3) Plans and Specifications for Track Tools

Collaborating with Committee 1—Roadway and Ballast and with Committee 22—Economics of Railway Labor

W. L. Roller (chairman, subcommittee), W. H. B. Bevan, E. W. Caruthers, H. R. Clarke, L. W. Deslauriers, J. A. Ellis, F. S. Hales, E. T. Howson, F. J. Jerome, J. H. Kelly, E. E. Martin, J. B. Myers, C. J. Rist, I. H. Schram, F. S. Schwinn, J. F. Shaffer, G. M. Strachan, J. M. Todd.

In collaboration with Committee 1—Railway and Ballast, and with Committee 22—Economics of Railway Labor.

In the Proceedings for 1938, Vol. 39, pages 406–409, are shown plans No. 20A—Wood Center Track Gage, No. 27—Track Level and Elevation Gage, No. 28—26-inch Scythe, No. 29—Snath and No. 30—Spot Board. These plans were offered as information and to invite comment and criticism.

Subsequent study and tests, based on comments and criticism received have resulted in extensive revisions of some of these plans.

Plan 27—Track Level with Elevation Gage has been revised and improved by incorporating more sensitive bubble.

Plan 29—Snath has been revised to provide a sturdier tool and more adaptable to railroad use.

Plan 20A—Wood Center Track Gage is unchanged.

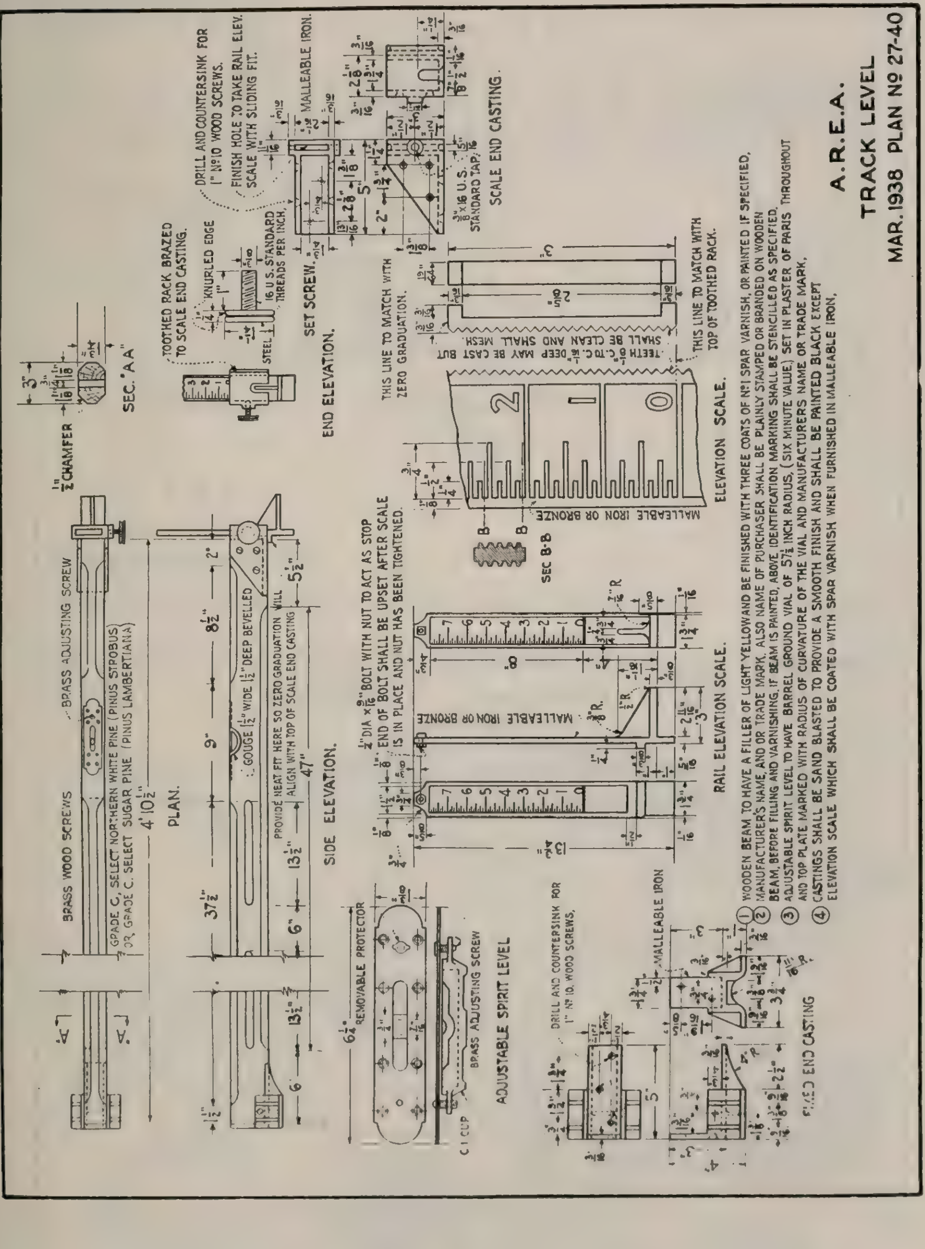
Plan 28—26-inch Scythe has been revised as to dimensions.

Plan 30—Spot Board is unchanged.

In the Proceedings for 1938, Vol. 40, page 564, is shown Plan No. 8A—Timber Tongs. This plan was offered as an alternate design to Plan No. 8—Timber Tongs, shown in the Manual for 1936, page 5–58, and for information, with the understanding that it would be offered later for adoption as Plan No. 8 in substitution for the present design.

In the Proceedings for 1939, Vol. 40, page 563, the following Physical Test for Timber Tongs was offered as information.

Three pairs of tongs to be tested from each lot of 10 dozen or less by suspending a load of 300 pounds to 400 pounds workwise in the tongs with the handles in a horizontal


BRASS WOOD SCREWS
BRASS ADJUSTING SCREW
GRADE C, SELECT NORTHERN WHITE PINE (PINUS STROBUS) OR GRADE C. SELECT SUGAR PINE (PINUS LAMBERTIANA)
4'10½"
PLAN.
A
A
½" CHAMFER
3"
SEC. 'A A'
37½"
9"
8½"
2"
13½"
6"
13½"
47"
5½"
6
GOUGE 1½" WIDE 1½" DEEP BEVELLED
PROVIDE NEAT FIT HERE SO ZERO GRADUATION WILL ALIGN WITH TOP OF SCALE END CASTING
SIDE ELEVATION.
TOOTHED RACK BRAZED TO SCALE END CASTING.
KNURLED EDGE
STEEL
16 U.S. STANDARD THREADS PER INCH.
SET SCREW.
END ELEVATION.
DRILL AND COUNTERSINK FOR 1" Nº10 WOOD SCREWS.
FINISH HOLE TO TAKE RAIL ELEV. SCALE WITH SLIDING FIT.
MALLEABLE IRON.
⅜"x16 U.S. STANDARD TAP.
SCALE END CASTING.
THIS LINE TO MATCH WITH ZERO GRADUATION.
TEETH ⅛" C. TO C. 1/16" DEEP MAY BE CAST BUT SHALL BE CLEAN AND SHALL MESH.
THIS LINE TO MATCH WITH TOP OF TOOTHED RACK.
MALLEABLE IRON OR BRONZE
SEC B-B
ELEVATION SCALE.
½" DIA x 9/16" BOLT WITH NUT TO ACT AS STOP END OF BOLT SHALL BE UPSET AFTER SCALE IS IN PLACE AND NUT HAS BEEN TIGHTENED.
MALLEABLE IRON OR BRONZE
RAIL ELEVATION SCALE.
6¼"
REMOVABLE PROTECTOR
BRASS ADJUSTING SCREW
C I CUP
ADJUSTABLE SPIRIT LEVEL
DRILL AND COUNTERSINK FOR 1" Nº10. WOOD SCREWS.
MALLEABLE IRON
FIXED END CASTING

① WOODEN BEAM TO HAVE A FILLER OF LIGHT YELLOW AND BE FINISHED WITH THREE COATS OF Nº1 SPAR VARNISH, OR PAINTED IF SPECIFIED.

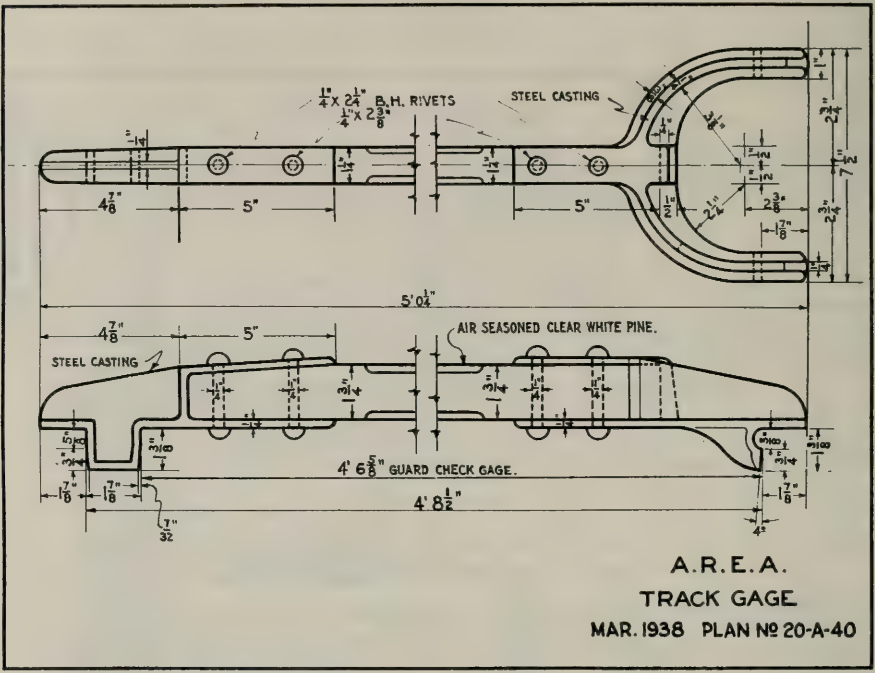
② MANUFACTURER'S NAME, AND OR TRADE MARK, ALSO NAME OF PURCHASER SHALL BE PLAINLY STAMPED OR BRANDED ON WOODEN BEAM, BEFORE FILLING AND VARNISHING. IF BEAM IS PAINTED, ABOVE IDENTIFICATION MARKING SHALL BE STENCILLED AS SPECIFIED.

③ ADJUSTABLE SPIRIT LEVEL TO HAVE BARREL GROUND VIAL OF 57½ INCH RADIUS, (SIX MINUTE VALUE,) SET IN PLASTER OF PARIS THROUGHOUT AND TOP PLATE MARKED WITH RADIUS OF CURVATURE OF THE VIAL AND MANUFACTURERS NAME OR TRADE MARK.

④ CASTINGS SHALL BE SAND BLASTED TO PROVIDE A SMOOTH FINISH AND SHALL BE PAINTED BLACK EXCEPT ELEVATION SCALE WHICH SHALL BE COATED WITH SPAR VARNISH WHEN FURNISHED IN MALLEABLE IRON.

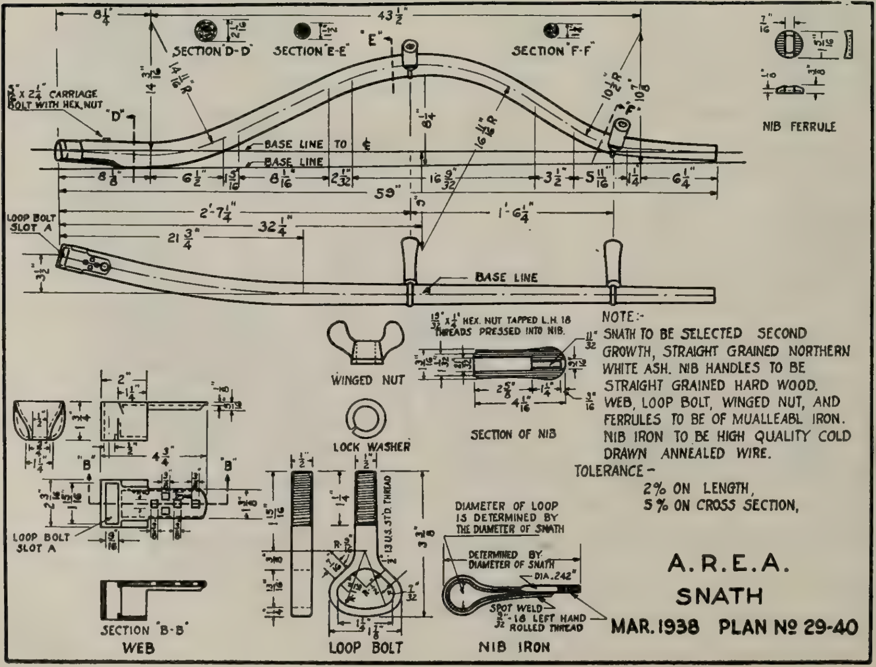
A.R.E.A.
TRACK LEVEL
MAR. 1938 PLAN Nº 27-40

20-A-40



A.R.E.A.
TRACK GAGE
MAR. 1938 PLAN No 20-A-40

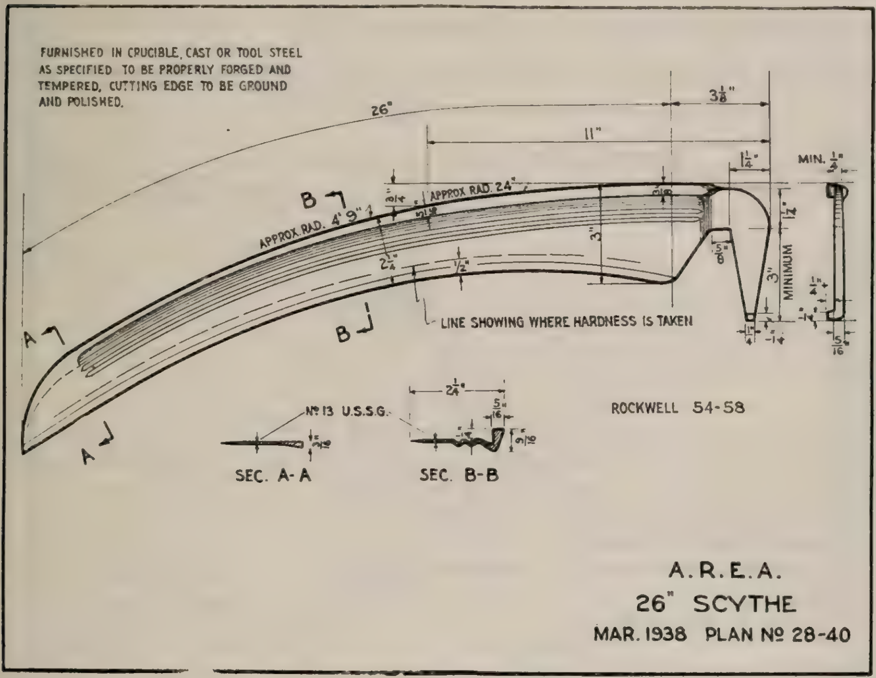
29-40



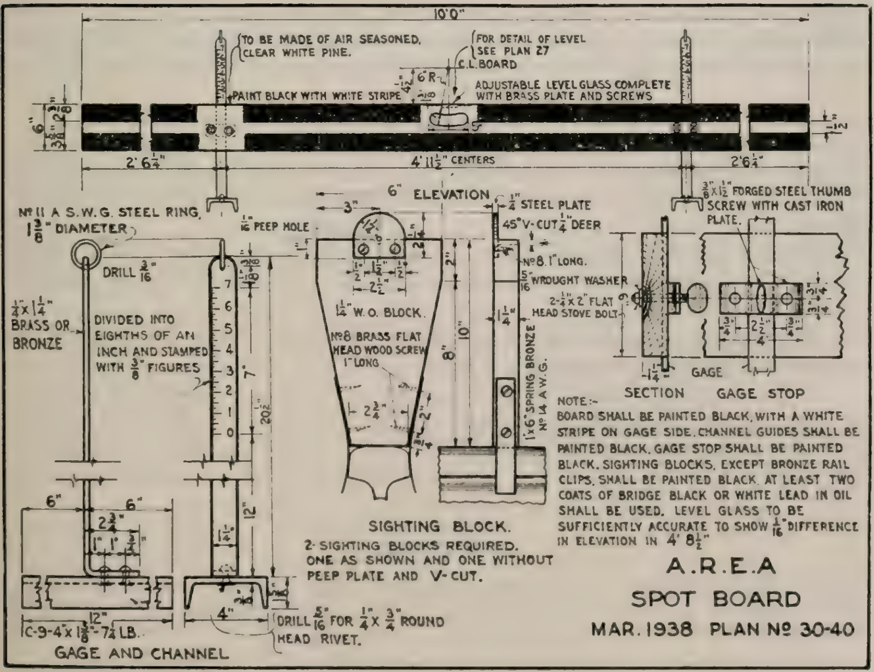
NOTE:-
SNATH TO BE SELECTED SECOND GROWTH, STRAIGHT GRAINED NORTHERN WHITE ASH. NIB HANDLES TO BE STRAIGHT GRAINED HARD WOOD. WEB, LOOP BOLT, WINGED NUT, AND FERRULES TO BE OF MUALLEABL IRON. NIB IRON TO BE HIGH QUALITY COLD DRAWN ANNEALED WIRE.
TOLERANCE -
2% ON LENGTH,
5% ON CROSS SECTION,

A.R.E.A.
SNATH
MAR. 1938 PLAN No 29-40

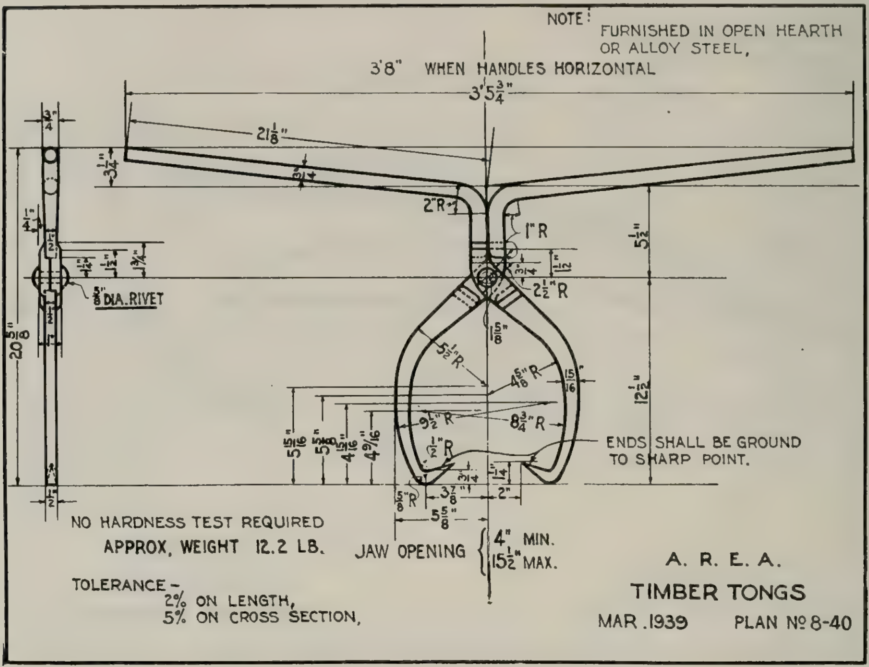
28-40


FURNISHED IN CRUCIBLE, CAST OR TOOL STEEL AS SPECIFIED TO BE PROPERLY FORGED AND TEMPERED, CUTTING EDGE TO BE GROUND AND POLISHED.
26"
11"
3⅛"
1¼"
MIN. ¼"
APPROX RAD. 24"
APPROX RAD. 4' 9"
B
A
3"
2¼"
½"
5/8"
3"
MINIMUM
1¾"
LINE SHOWING WHERE HARDNESS IS TAKEN
5/16
2¼"
No 13 U.S.S.G.
SEC. A-A
SEC. B-B
ROCKWELL 54-58
A.R.E.A.
26" SCYTHE
MAR. 1938 PLAN No 28-40

30-40


10'0"
TO BE MADE OF AIR SEASONED, CLEAR WHITE PINE.
FOR DETAIL OF LEVEL SEE PLAN 27
C.L. BOARD
6" R
PAINT BLACK WITH WHITE STRIPE
ADJUSTABLE LEVEL GLASS COMPLETE WITH BRASS PLATE AND SCREWS
6"
2' 6¼"
4' 11½" CENTERS
2' 6¼"
ELEVATION
No 11 A S.W.G. STEEL RING, 1⅜" DIAMETER
1/16 PEEP HOLE
DRILL 3/16"
¼"x 1¼" BRASS OR BRONZE
DIVIDED INTO EIGHTHS OF AN INCH AND STAMPED WITH 3/8" FIGURES
7 6 5 4 3 2 1 0
7"
20½"
12"
1¼"
6"
6"
2¾"
1" 1" ¾"
C-9-4"x 1⅜"-7¼ LB.
12"
4"
DRILL 5/16" FOR ¼"x ¾" ROUND HEAD RIVET.
GAGE AND CHANNEL
3"
6"
1¼" W.O. BLOCK.
No 8 BRASS FLAT HEAD WOOD SCREW 1" LONG
2¾"
2½"
10"
8"
¼" STEEL PLATE
45° V-CUT ¼" DEEP
No 8. 1" LONG.
5/16 WROUGHT WASHER
2-¼"x 2" FLAT HEAD STOVE BOLT
1¼"
1"x 6" SPRING BRONZE No 14 A.W.G.
SIGHTING BLOCK.
2-SIGHTING BLOCKS REQUIRED. ONE AS SHOWN AND ONE WITHOUT PEEP PLATE AND V-CUT.
⅜"x 1½" FORGED STEEL THUMB SCREW WITH CAST IRON PLATE.
1¼"
¾" 2½" ¾"
4"
GAGE
SECTION
GAGE STOP
NOTE:-
BOARD SHALL BE PAINTED BLACK, WITH A WHITE STRIPE ON GAGE SIDE. CHANNEL GUIDES SHALL BE PAINTED BLACK. GAGE STOP SHALL BE PAINTED BLACK. SIGHTING BLOCKS, EXCEPT BRONZE RAIL CLIPS, SHALL BE PAINTED BLACK. AT LEAST TWO COATS OF BRIDGE BLACK OR WHITE LEAD IN OIL SHALL BE USED. LEVEL GLASS TO BE SUFFICIENTLY ACCURATE TO SHOW 1/16" DIFFERENCE IN ELEVATION IN 4' 8½"
A.R.E.A
SPOT BOARD
MAR. 1938 PLAN No 30-40

8-40


NOTE: FURNISHED IN OPEN HEARTH OR ALLOY STEEL.
3'8" WHEN HANDLES HORIZONTAL
3'5¾"
21⅛"
¾"
3¼"
¾"
2"R
1"R
¼"
½"
1½"
1¾"
2½"R
⅝" DIA. RIVET
20⅝"
5½"
12½"
1⅝"
5½"R
4⅝"R
15/16"
9½"R
8¾"R
½"R
5 15/16"
5 5/16"
4 15/16"
4 9/16"
⅝"R
3⅞"
2"
5⅝"
ENDS SHALL BE GROUND TO SHARP POINT.
NO HARDNESS TEST REQUIRED
APPROX. WEIGHT 12.2 LB.
JAW OPENING 4" MIN. 15½" MAX.
TOLERANCE – 2% ON LENGTH, 5% ON CROSS SECTION.
A. R. E. A.
TIMBER TONGS
MAR. 1939
PLAN Nº 8-40

position and supported at a point 2 inches from the end. Deflection with 300-pound weight shall not exceed 1 inch, with no permanent set, and with 400-pound weight deflection shall not exceed 1¼ inches and with a permanent set of not to exceed ⅛ inch.

Conclusions

It is recommended that Plans 20A, 27, 28, 29 and 30, with suffix—40 added to indicate year of adoption, be accepted as recommended practice and printed in the Manual.

It is recommended that present plan No. 8A—Timber Tongs, be accepted as recommended practice and printed in Manual as Plan No. 8-40, and that present plan be withdrawn.

It is also recommended that Physical Test for Timber Tongs be adopted as recommended practice and published in Manual.

It is recommended that the subject be continued.

Appendix E

(4) Plans for Switches, Frogs, Crossings, Spring and Slip Switches

Collaborating with Signal Section

Track Construction in Paved Streets

Collaborating with Committee 9—Highways on Matters Pertaining to Track Construction in Paved Streets

E. W. Caruthers (chairman, subcommittee), L. L. Adams, W. H. Bettis, L. H. Bond, C. W. Breed, O. U. Cook, E. D. Cowlin, H. Q. Day, L. W. Deslauriers, J. A. Ellis, O. H. Frick, N. M. Hench, F. W. Hillman, A. F. Huber, W. G. Hulbert, C. T. Jackson, A. A. Johnson, K. R. McLennan, L. I. Martin, F. H. Masters, R. E. Miller, W. A. Murray, J. B. Myers, G. A. Peabody, S. H. Poore, J. A. Reed, O. C. Rehfuss, C. J. Rist, I. H. Schram, G. L. Sitton, G. J. Slibeck, C. R. Strattman, J. N. Todd, H. N. West, R. P. Winton, J. G. Wishart, M. J. T. Zeeman.

During the past year the committee has undertaken a review of all the drawings and specifications which have been approved by the Association as recommended construction and published in the portfolio of Trackwork Plans.

Study and discussion indicated that before reprinting, practically all the plans require more or less revision to bring them into line with the best current practice. However, as facilities were not available to carry out such revision of all the plans within a period of one year the committee now offers for adoption *key* plans of the various types and classes of material, the thought being that if these be approved the revision of the remaining plans will be undertaken during the coming year.

The aim has been to strengthen and otherwise improve the various track structures shown, at the same time looking toward simplification and economy by avoiding a multiplicity of designs, to which end many of the alternates shown on the plans as last issued have been eliminated. It should be said, however, that while the committee has endeavored to select the best, it recognizes that designs other than those shown are also good and entirely safe.

During recent years adjustable rail braces have come into rather general use for main track switches, and their advantage and superiority over rigid braces has been established. Therefore, in redrawing the switches, adjustable braces have been shown as preferred construction, but provision is made for rigid braces when wanted.

The use of twin tie plates makes for economy, due to their design being such that a very few kinds cover the requirements for a great many different locations. They are therefore shown on several of the redrawn switch and frog plans.

To avoid any possibility of confusion or misunderstanding as to what issue is meant when any of the plans is referred to by number, it is proposed to incorporate the year of issue as an integral part of the plan number. For example, Plan No. 701–40 means the 1940 issue of the plan the basic number of which is 701.

The Standardization committee of the Manganese Track Society co-operated in the preparation of the plans and specifications, rendered valuable assistance, and contributed all of the necessary drafting work.

Conclusions

The committee offers the plans listed below with the recommendation that they be adopted as recommended practice and published in the Manual.

Plans ready for printing and inserting in portfolio of Trackwork Plans.

Plan No.	*Title*	*Remarks*
111–40	16′ 6″ Straight Split Switch with Uniform Risers.	Supersedes Plan No. 101, Revised March, 1934.
112–40	16′ 6″ Straight Split Switch with Graduated Risers.	Supersedes Plan No. 102, Revised March, 1934.
221–40	Details for Switch Points.	Supersedes in part Plans Nos. 101 to 108 incl., 201 and 204 Revised March, 1934, Plan No. 215 Adopted March, 1937, and Plan No. 140, Adopted March, 1938.
222–40	Switch Rods and Clips.	Supersedes in part Plans Nos. 201, 202, 205 and 206, Revised March, 1934.
223–40	Swtch Plates and Rigid Rail Braces.	Supersedes in part Plans Nos. 201, 202, 205, 206 and 207. Revised March, 1934.
224–40	Switch Plates and Adjustable Rail Braces.	Supersedes in part Plan No. 240 Revised March, 1935 and Plan No. 215 Adopted March, 1937.
241–40	Details and typical Applications of Twin Tie Plates.	Supersedes Plan No. 326 Revised March, 1934.
401–40	No. 10 Spring Rail Frog.	Revision of Plan No. 401 as revised March, 1934; also supersedes Plan No. 404 Revised March, 1934.
405–40	No. 10 Spring Rail Frog; Short Spring-Rail Type.	Supersedes Plan No. 405 Adopted March, 1939.
502–40	Setting for Guard Rails; Tee-Rail Design.	Supersedes Plan No. 502, Revised March, 1934.
503–40	Guard Rails; Tee-Rail Design with Planed Flares and Canted Plates.	Companion plan to Plan No. 504–40, but showing canted instead of flat plates.
504–40	Guard Rails; Tee-Rail Design with Planed Flares and Flat Plates.	Supersedes Plan No. 504 Revised March, 1934.
505–40	Specifications for Guard-Rail Clamps.	Revision of Plan No. 505. Adopted March, 1934.
510–40	Manganese Steel One-Piece Guard Rails.	Revision of Plan No. 510 as revised March, 1934.
590–40	Diagram Illustrating Preferred Names of Parts for Guard Rails.	Revision of Plan No. 590 as revised March, 1934.
640–40	Data and Sections for Solid Manganese Steel Self-Guarded Frogs.	Revision of Plan No. 640 as revised March, 1938.
670–40	Data and Sections for Solid Manganese Steel Frogs.	Revision of Plan No. 670 as revised March, 1938.
701–40	Bolted Rail Crossings, Angles 90° to 50° inclusive, Three-Rail Design.	Revision of Plan No. 701 as revised March, 1934.
751–40	Designs and Dimensions of Manganese Steel Inserts for Crossings of Angles from 14°15′ to 45°00′.	Supersedes Plan No. 751 Revised March, 1934.
771–40	Solid Manganese Steel Crossings, Angles 90° to 60°, inclusive.	Revision of Plan No. 771 as revised March, 1934.
772–40	Solid Manganese Steel Crossings, Angles below 60° to 40°, inclusive.	Revision of Plan No. 772 as revised March, 1934.
773–40	Solid Manganese Steel Crossings, Angles below 40° to 25°, inclusive.	Revision of plan No. 773 as revised March, 1934.
776–40	Solid Manganese Steel Crossings, Steam Railroad over Electric Railway Angles 90° to 60°, inclusive.	Revision of Plan No. 776 as revised March, 1934.
777–40	Solid Manganese Steel Crossings, Steam Railroad over Electric Railway Angles below 60° to 40°, inclusive.	Revision of Plan No. 777 as revised March, 1934.

Plan No.	*Title*	*Remarks*
780–40	Solid Manganese Steel Crossings for 7" and 9" Girder Rails, Angles 90° to 60°, inclusive, for Steam Railroad over Electric Railway and for Steam Railroad Tracks both ways.	Revision of Plan No. 780 as revised March, 1934.
781–40	Solid Manganese Steel Crossings for 7" and 9" Girder Rails, Angles below 60° to 40°, inclusive, for Steam Railroad over Electric Railway and for Steam Railroad Tracks both ways.	Revision of Plan No. 781 as revised March, 1934.
793–40*	Data Sheet for A.A.R. Standard Wheel Flanges, Treads and Gages.	Revision of Plan No. 793 as revised March, 1935.
1001–40*	Data for Tee-Rail Sections.	Revision of Plan No. 1001 as revised March, 1934.
1002–40*	Girder Rail Sections.	Revision of Plan No. 1002 as revised March, 1934.
1003–40*	Data Sheet for A.T.E.A. Girder Grooved Rails, Girder Guard Rails and Plain Girder Rails.	Revision of Plan No. 1003 as revised March, 1934.
1004–40*	Data for Head-Free Rail Sections.	Revision of Plan No. 1004 as revised March, 1934.
1005–40	Beveling of Rail Ends for Special Trackwork.	Supersedes data in Appendix A, Section 36A, adopted March, 1938.

In view of the issuance of the plans listed above the committee recommends withdrawal of the following plans from the portfolio:—

101	Rev. 1934	16' 6" Split Switch with Uniform Risers.	Superseded by Plan No. 111–40.
102	Rev. 1934	16' 6" Split Switch with Graduated Risers.	Superseded by Plan No. 112–40.
263	Rev. 1934	No. 11 Frogs for Medium Weight Rails.	The lengths shown for rail-bound manganese steel, bolted rigid and spring-rail frogs are being discontinued as standard in favor of the lengths shown on Plans Nos. 278, 279, 281, 282, 283, 291 and 292, respectively.
264	Rev. 1934	No. 12 "	
265	Rev. 1934	No. 14 "	
266	Rev. 1934	No. 15 "	
267	Rev. 1934	No. 16 "	
268	Rev. 1934	No. 18 "	
269	Rev. 1934	No. 20 "	
271	Rev. 1934	No. 4 Frogs with Uniform Tie Spacing for Heavy and Medium Weight Rails.	The lengths shown for rail-bound manganese steel, bolted rigid and spring-rail frogs are being discontinued as standard in favor of the lengths shown on Plans Nos. 256 to 262, inclusive.
272	Rev. 1934	No. 5 "	
273	Rev. 1934	No. 6 "	
274	Rev. 1934	No. 7 "	
275	Rev. 1934	No. 8 "	
276	Rev. 1934	No. 9 "	
277	Rev. 1934	No. 10 "	
301–3	Rev. 1934	No. 6, 7, and 8 Bolted Rigid Frogs.	Now obsolete due to revision of recommended lengths as explained above.
304–6	Rev. 1934	No. 10 and 11 Bolted Rigid Frogs.	
309	Rev. 1934	No. 4 and 5 Bolted Rigid Frogs.	
325	Rev. 1935	Frog Fillers for Rails 80-lb. per Yard and Heavier.	Obsolete in part and not deemed of sufficient value to warrant revising and reprinting.
326	Rev. 1934	Detail of Tie Plates and Base Plates for Rail Bound Manganese Steel, Bolted Rigid and Solid Manganese Steel Frogs.	Superseded by Plan No. 241–40.

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* These drawings are sheets of information rather than recommended practice.

Plan No.	*Title*	*Remarks*
341–2 Rev. 1934	No. 6 and No. 7 Self-Guarded Frogs—Bolted Rigid Type.	Being discontinued as the little use of self-guarded frogs of this type does not warrant the revising and reprinting of the plans.
343–4 Rev. 1934	No. 8 and No. 10 Self-Guarded Frogs—Bolted Rigid Type.	
345 Adopt. 1934	Data and Sections—Self-Guarded Frogs—Bolted Rigid Type.	
346 Adopt. 1934	No. 6, No. 7, No. 8 and No. 10 Self-Guarded Frogs—Bolted Rigid Type.	
401 Rev. 1934	No. 10 Spring-Rail Frog for Medium Weight Rails.	Superseded by Plan No. 401–40.
404 Rev. 1934	No. 10 Spring-Rail Frog for Heavy and Medium Weight Rails.	
405 Adopt. 1939	No. 10 Spring-Rail Frog—Short Spring-Rail Type.	Superseded by Plan No. 405–40.
502 Rev. 1934	Details of Tie Plates and Setting for Guard Rails—Tee-Rail Design.	Superseded by Plan No. 502–40.
503 Rev. 1934	Guard Rails—Tee-Rail Design with Bent Flares.	Being discontinued in favor of the preferred design covered by Plans Nos. 503–40 and 504–40.
504 Rev. 1934	Guard Rails—Tee-Rail Design with Planed Flares.	Superseded by Plan No. 504–40.
505 Adopt. 1934	Specifications for Guard Rail Clamps.	Superseded by Plan No. 505–40.
510 Rev. 1934	Manganese Steel One-Piece Guard Rails.	Superseded by Plan No. 510–40.
590 Rev. 1934	Preferred Names of Parts for Guard Rails.	Superseded by Plan No. 590–40.
640 Rev. 1938	Data and Sections for Solid Manganese Steel Self-Guarded Frogs.	Superseded by Plan No. 640–40.
643 Rev. 1934	No. 7, No. 8 and No. 10 Solid Manganese Steel Self-Guarded Frogs.	Discontinued as data is shown on Plan No. 640–40.
651–3 Rev. 1934	No. 6, No. 7 and No. 8 Solid Manganese Steel Frogs.	Discontinued as data is shown on Plan No. 670–40.
654–5 Rev. 1934	No. 10 and No. 11 Solid Manganese Steel Frogs.	
656 Rev. 1934	No. 4 and No. 5 Solid Manganese Steel Frogs.	
670 Rev. 1938	Data and Sections for Solid Manganese Steel Frogs.	Superseded by Plan No. 670–40.
701 Rev. 1934	Bolted Rail Crossings, Angles 90°00′ to 50°00′, inclusive, 3-Rail Design.	Superseded by Plan No. 701–40.
751 Rev. 1934	Manganese Steel Insert Crossings—Designs and Dimensions of Manganese Steel Inserts for Angles 45°00′ to 14°15′, Detail "A".	Superseded by Plan No. 751–40.
752 Rev. 1934	Manganese Steel Insert Crossings—Designs and Dimensions of Manganese Steel Inserts for Angles 45°00′ to 14°15′, Detail "B".	This design being discontinued in favor of that shown on Plan No. 751–40.
762 Rev. 1934	Manganese Steel Insert Crossings—for Angles Below 45°00′ to 35°00′ inclusive, Detail "B"—Three-Rail Design.	

Plan No.	*Title*	*Remarks*
763	Rev. 1934 Manganese Steel Insert Crossings for Angles Below 35°00′ to 25°00′ inclusive, Detail "B"—Three-Rail Design.	This design being discontinued in favor of that shown on Plan No. 751–40.
764	Rev. 1934 Manganese Steel Insert Crossings for Angles Below 35°00′ to 25°00′, inclusive, Detail "B"—Two-Rail Design.	
765	Rev. 1934 Manganese Steel Insert Crossings for Angles Below 25°00′ and above 14°15′, Detail "B"—Two-Rail Design.	
766	Rev. 1934 Manganese Steel Insert Crossings for Angles Below 25°00′ and above 14°15′, Detail "B"—Single-Rail Design.	
771	Rev. 1934 Solid Manganese Steel Crossings for Angles 90°00′ to 60°00′, inclusive.	Superseded by Plan No. 771–40.
771-B	Rev. 1934 Solid Manganese Steel Crossings for Angles 90°00′ to 60°00′, inclusive—Design No. 2 and Design No. 3.	Discontinued on account of little use of these designs.
772	Rev. 1934 Solid Manganese Steel Crossings for Angles Below 60°00′ to 40°00′, inclusive.	Superseded by Plan No. 772–40.
773	Rev. 1934 Solid Manganese Steel Crossings for Angles Between 40°00′ to 25°00′, inclusive.	Superseded by Plan No. 773–40.
776	Rev. 1934 Solid Manganese Steel Crossings, Steam Railroad over Electric Railway, for Angles 90°00′ to 60°00′, inclusive.	Superseded by Plan No. 776–40.
777	Rev. 1934 Solid Manganese Steel Crossings, Steam Railroad over Electric Railway, for Angles Below 60°00′ to 40°00′, inclusive.	Superseded by Plan No. 777–40.
778	Rev. 1934 Manganese Steel Insert Crossings, Steam Railroad over Electric Railway, Angles 45°00′ to 30°00′, inclusive.	Discontinued on account of little use of this design.
780	Rev. 1934 Solid Manganese Steel Crossings for 7″ and 9″ Girder Rails—Angles 90°00′ to 60°00′, inclusive.	Superseded by Plan No. 780–40.
781	Rev. 1934 Solid Manganese Steel Crossings for 7″ and 9″ Girder Rails—Angles 60°00′ to 40°00′, inclusive.	Superseded by Plan No. 781–40.
793	Rev. 1935 Data Sheet for AAR Standard Wheel Flanges, Treads and Gages.	Superseded by Plan No. 793–40.
1001	Rev. 1934 Data Sheet for Tee-Rail Sections.	Superseded by Plan No. 1001–40.
1002	Rev. 1934 Girder Rail Sections.	Superseded by Plan No. 1002–40.
1003	Rev. 1934 Data Sheet for A.T.E.A. Girder Grooved Rails, Girder Guard Rails and Plain Girder Rails.	Superseded by Plan No. 1003–40.
1004	Rev. 1934 Data Sheet for Head-Free Rail Sections.	Superseded by Plan No. 1004–40.
Appendix "D"	Additional Alternates.	All the data is now shown elsewhere.

Appendix F

(5) Corrosion of Rails and Fastenings in Tunnels

Collaborating with Committee 4—Rail

A. E. Perlman (chairman, subcommittee), W. H. Bettis, R. W. E. Bowler, O. U. Cook, L. W. Deslauriers, T. T. Irving, E. E. Martin, S. H. Poore, G. L. G. Smith, G. M. Strachan, H. von Schrenk.

During the past year, your committee has continued its study, both in the laboratory and in the field, to determine methods for elimination of corrosion of rail and fastenings in tunnels.

The protection of the running surface of the rail from corrosion is the most important problem. The average corrosion penetration found to date has been 0.015 in. per year. Measurements of the rate of corrosion are being made in the Moffatt tunnel, 6.2 miles in length, by the two following methods:

1. The use of a rail profile machine with which the actual profile measurements are sketched from time to time.
2. Measurements made with an Ames dial reading to 0.001 in. Special clamps were made and fastened to the bottom of the rail at various locations for the purpose of making measurements of the rate of wear on the running surface. Also, a short piece of rail with clamps is used as a standard measure and is kept in the tunnel.

The possible methods of eliminating corrosion investigated are listed below:

a. Treatment of locomotive coal to neutralize stack gases.—Tests were made adding lime from a special feeder equipped on locomotives. These tests indicated that lime did not afford any protection.

b. Protective coatings for tie plates, base and web of rail.—Protective coatings of various types of oils, special corrosion-resistant petroleum base compounds, dichromate treatments, lacquers, and various types of paints were applied on both test specimens and rail and fastenings, and it was found the corrosive agents of the stack gases eventually penetrated all of these materials. Coatings of about 0.01 in. thick were penetrated in approximately 45 days. Also, since none of these coatings could be kept on the running surface of the rail, the investigation is being conducted to find some method of first securing this protection.

c. Special alloy materials.—Various types of alloying materials for steel were tried, including chrome, nickel, silicon, and copper. It was found that most of these materials had practically the same initial corrosion rate as the standard rail steel and that the alloying agents usually resulted in a retarded corrosion rate after a fairly heavy coating of oxide had been built up on the surface. Since it is necessary to protect the running surface, these materials with a high initial rate of corrosion were found to be unsatisfactory.

d. Metal spray on sides of head of rail.—A modified cathodic protection system in the form of a zinc spray on the sides of the head of the rail is being tested. The zinc will protect the iron cathodically some distance from itself. Measurements are being made monthly on this test section to determine if the running surface of the rail can be protected.

Wrought iron spikes and galvanized spikes are now being tested at various locations in the tunnel. Consideration is being given to rolling a special rail section for use in tunnels.

This is submitted as a progress report.

Appendix G

(6) Design of Tie Plates for RE Rail Sections as Developed

Collaborating with Committees 3—Ties and 4—Rail

J. de N. Macomb (chairman, subcommittee), E. W. Caruthers, H. R. Clarke, J. A. Ellis, G. L. Sitton, G. M. Strachan.

The following specifications for hot-worked, high-carbon steel tie plates have been prepared. It is recommended that they be adopted as recommended practice and printed in the Manual.

Specifications for Hot-Worked, High-Carbon Steel Tie Plates

I MANUFACTURE

101. (a) The steel shall be made by one or more of the following processes: Open-hearth or electric-furnace.

(b) Cold steel accumulated in the form of ingots or billets which meet the chemical requirements of Section 201 may be used.

(c) The tie plates shall be punched, slotted and sheared hot at a temperature which will give the best results, and immediately thereafter placed in an enclosure to insure slow cooling from the initial heat.

II CHEMICAL PROPERTIES AND TESTS

201. The steel shall conform to the following requirements as to chemical composition:

	Open-Hearth or Electric-Furnace
Carbon, percent	0.40 to 0.80
Phosphorus, max. percent	0.05
Copper (when specified) min. percent	0.20

202. (a) An analysis of each melt of open-hearth or electric-furnace steel shall be made by the manufacturer to determine the percentages of carbon and phosphorus; also copper when copper steel is specified. This analysis shall be made from drillings taken at least ⅛ inch beneath the surface of a test ingot obtained during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 201.

(b) Ladle analysis of cold steel correctly identified by melt number may be taken from the mill record.

III PHYSICAL PROPERTIES AND TESTS

301. Bend test specimens shall be taken from the finished tie plates, longitudinally with the direction of rolling. They shall be rectangular in section, the width of the specimen being not less than the average thickness, and shall have two faces as rolled. They shall be free from ribs or projections. Where the design of the tie plates is such that specimens cannot be taken between the ribs or projections, these ribs or projections shall, in preparing the specimen, be planed off even with the main surface of the tie plate.

302. The bend test specimens specified in Section 301 shall stand being bent cold through 30 degrees around a pin the diameter of which is equal to three times the thickness of the specimen without cracking on the outside of the bent portion.

303. If preferred by the manufacturer, the following bend test may be substituted for that described in Section 302.

304. A finished tie plate may be bent in either direction. This test shall stand being bent cold through 30 degrees around a pin the diameter of which is equal to three times the thickness of the specimen where bent, without cracking on the outside of the bent portion. The term "thickness" includes vertical height of ribs and shoulder where they are transverse to direction of pin.

305. (a) One bend test shall be made from each identified melt, or from each 25 tons where melts are not identified.

(b) Tie plates represented by bend tests failing to meet the above requirements, may be annealed and resubmitted. If tie plates fail to meet the third test they shall be rejected.

IV WORKMANSHIP AND FINISH

401. The tie plates shall conform to the dimensions specified by the purchaser, with the following permissible variations:

(a) For tie plates with shoulders parallel to the direction of rolling, a variation of $\frac{1}{32}$ inch in thickness, $\frac{1}{8}$ inch in rolled width, and $\frac{3}{16}$ inch in sheared length will be permitted.

(b) For tie plates with rolled crown a variation of $\frac{1}{32}$ inch in thickness, $\frac{3}{16}$ inch in rolled width and $\frac{1}{4}$ inch in sheared length will be permitted.

(c) A variation of $\frac{1}{64}$ inch in flatness of rail seat will be permitted.

(d) A tolerance of $\frac{1}{16}$ inch shall be permitted in excess of the minimum dimension specified for distance between the shoulders of double shoulder tie plates.

(e) A variation of not more than $\frac{1}{32}$ inch in the location of spike holes and in the length of their sides will be permitted.

(f) Regardless of variations otherwise permissible, the weights to be paid for shall not exceed by more than 3 percent the weights calculated from the specified dimensions.

402. The tie plates shall be smoothly rolled, true to templet, and free from injurious warp and other imperfections in surface and projecting fins of metal caused by shearing and punching.

V MARKING

501. The name or brand of the manufacturer, the section of the tie plate, year of manufacture and the letters "HW" indicating hot worked, shall be rolled in raised letters and figures on the tops of the tie plates outside the shoulders, and a portion of this marking shall appear on each finished tie plate.

VI INSPECTION AND REJECTION

601. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the tie plates ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the tie plates are being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

602. (a) Tie plates failing to meet the requirements of these specifications will be rejected.

(b) Tie plates which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Appendix H

(8) Welding of Manganese Castings in Special Trackwork

Collaborating with Committee 27—Maintenance of Way Work Equipment

F. J. Bishop (chairman, subcommittee), Lem Adams, A. L. Bartlett, W. H. Bettis, E. W. Caruthers, H. Q. Day, O. H. Frick, H. H. Harman, F. W. Hillman, W. G. Hulbert, C. T. Jackson, G. M. Magee, L. I. Martin, F. H. Masters, R. E. Miller, G. A. Peabody, O. C. Rehfuss, I. H. Schram, G. J. Slibeck, H. N. West, R. P. Winton, M. J. T. Zeeman.

A report on this subject, presented to the Association in 1938, may be found in Vol. 39 of Proceedings, pages 416 to 419 inclusive.

After a study of all the available data on the welding of manganese castings in special trackwork, the committee decided that some research work was necessary in order to improve the technique of manganese welding, and to determine the relative merits of coated electrodes and the advantage or disadvantage of nickel-manganese and other alloy-manganese base metal for castings. Accordingly a program of research was prepared, the scope of which is shown below:

Scope of Research Program

1. Effect of different currents and amperages
2. Effect of different compositions of rods
3. Effect of use of cutting torch
4. Effect of welding with filler bars
5. Effect of welding on preground surface
6. Welding with a.c. versus d.c. power
7. Effect of welding on nickel manganese steel and initial properties of nickel-manganese compared to high manganese
8. Effect of coating on welding rods
9. Effect of temperature on welding
10. Effect of peening during welding
11. Effect of welding in wind or rain
12. Effect of treating manganese after welding
13. Testing welds by magnetic induction

This research program is designed to determine the most economical and effective welding technique and will result in definite savings to the railway industry by the elimination of unnecessary operations in welding and longer service life of welds.

In order to obtain reliable information, the research plan proposes the establishment of a "proving ground" where the different welding techniques and recommended materials will be compared under actual, equal, and identical traffic conditions—the welding tests to be supplemented by such laboratory work as may be found necessary.

Through the assistance of the frog and switch manufacturers, your committee has obtained 24 special manganese test castings. These castings have been assembled in 3 units and have been installed by the Chicago, Milwaukee, St. Paul & Pacific Railroad in one of its heavy traffic freight tracks near Mannheim, Ill.

Your committee is indebted to the Milwaukee for the installation of the test castings as well as for furnishing the necessary rail for the casting assemblies and complete guard rail assemblies. The Welding department on the Milwaukee will make all of the test welds required. We are likewise indebted to the following frog and switch manufacturers—

One of the Test Castings, Two Others in the Background.

Pettibone Mulliken Corporation
The American Manganese and Ramapo Ajax Divisions of the American Brake Shoe & Foundry Company
The Morden Frog & Crossing Works
The Cleveland Frog & Crossing Company

These manufacturers have furnished all the necessary castings, plates, etc. and have fabricated the three complete assembly units.

The Association of American Railroads has appropriated $1,000 for use in 1940 in carrying out the research program.

It is recommended that this subject be continued.

Appendix I

(9) Bolt Tension Necessary for Proper Supporting of Joints

C. W. Breed (chairman, subcommittee), C. W. Baldridge, A. L. Bartlett, E. D. Cowlin, L. W. Deslauriers, H. F. Fifield, O. H. Frick, J. W. Fulmer, C. J. Geyer, F. S. Hales, C. T. Jackson, J. de N. Macomb, G. M. Magee, W. A. Murray, S. H. Poore, J. N. Todd.

Continuing the work of the subcommittee, as reported last year, measurements of bolt tension have been made at intervals on the test installations on the Chicago, Burlington & Quincy, the Chicago, Milwaukee, St. Paul & Pacific, and the Denver Rio Grande Western. In addition, test sections have been installed on other railways during the year. The results of the work performed upon each individual test installation are given below:

Burlington Test Installation

The bolt test installation on the C. B. & Q. near Western Springs, Ill., was described in last year's report. This test was laid with new 131-lb. rail, 6-hole toeless joint bars of both head-free and head-contact types, 1-inch heat-treated track bolts, and Triflex and double-coil Improved Hipower spring washers.

Uniformity of Bolt Tension Obtained in Tightening

The rail on this test was laid new August 9, 1938, and the bolt tension was measured as described in last year's report. Since many of the bolts had been tightened beyond their elastic limit, on October 5, 1938, the bolts were loosened and new "no load" measurements made. At that time it was desired to give all bolts on the south rail approximately 15,000 lb. tension, and on the north rail, 25,000 to 30,000 lb. A specially designed hand wrench with a friction release was used for this tightening. This wrench consisted of a spool with a cut-out portion in the center to fit over the track nut. The handle on the wrench was clamped to this spool by means of two jaws and a bolt. When the track man had applied sufficient torque to overcome the friction of the jaws on the spool, the handle would then turn about the spool and no further tightening of the bolt would result. The setting of this friction release wrench was made by tightening the adjustment bolt on the clamps until the desired tension was obtained on a test bolt in track as determined by means of bolt tension extensometer readings. After the wrench had been set to give the desired bolt tension all bolts were tightened and the applied bolt tension was then measured. The chart (Fig. 1) shows the results obtained on the south rail. It will be noted that considerable variation in tension resulted and it is probable that as good or perhaps even better uniformity could be obtained by use of an ordinary hand wrench.

Loss of Bolt Tension Under Traffic

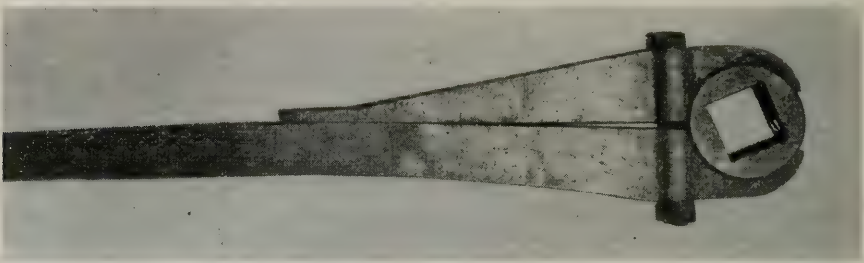
After the October 5, 1938 measurements of bolt tensions, the bolts were left undisturbed and measurements of bolt tension were repeated on November 1, 1938; November 30, 1938; April 25, 1939; and August 4, 1939. The average bolt tension applied and the average remaining at each of these dates of measurement is indicated in Fig. 2. It will be noted that the bolt tension decreased quite rapidly during the first four to eight weeks of service, after which period the rate of decrease has been much less rapid. Table 1 shows the average loss in bolt tension per month on each of the eight test sections.

TABLE 1

AVERAGE LOSS IN TENSION FROM OCTOBER 5, 1938 TO AUGUST 4, 1939

	Average Bolt Tension—Lb.			
	10/5/39	*8/4/39*	*Loss*	*Loss Per Month*
—South Rail—				
Head-free Triflex	14,740	6,164	8,576	860
Head-free Hipower	15,970	3,530	12,440	1,240
Head Contact Triflex	12,845	6,880	5,965	600
Head Contact Hipower	20,197	7,267	12,930	1,290
—North Rail—				
Head-free Triflex	24,580	11,300	13,280	1,330
Head-free Hipower	25,250	10,200	15,050	1,500
Head Contact Triflex	23,770	9,650	14,120	1,410
Head Contact Hipower	25,360	10,030	15,330	1,530

It will be noted that the rate of bolt tension loss is higher with the higher initial bolt tension. It is the intention to retighten the bolts and continue measurements another year before drawing definite conclusions.



A Wrench With a Frictional Release Was Used.

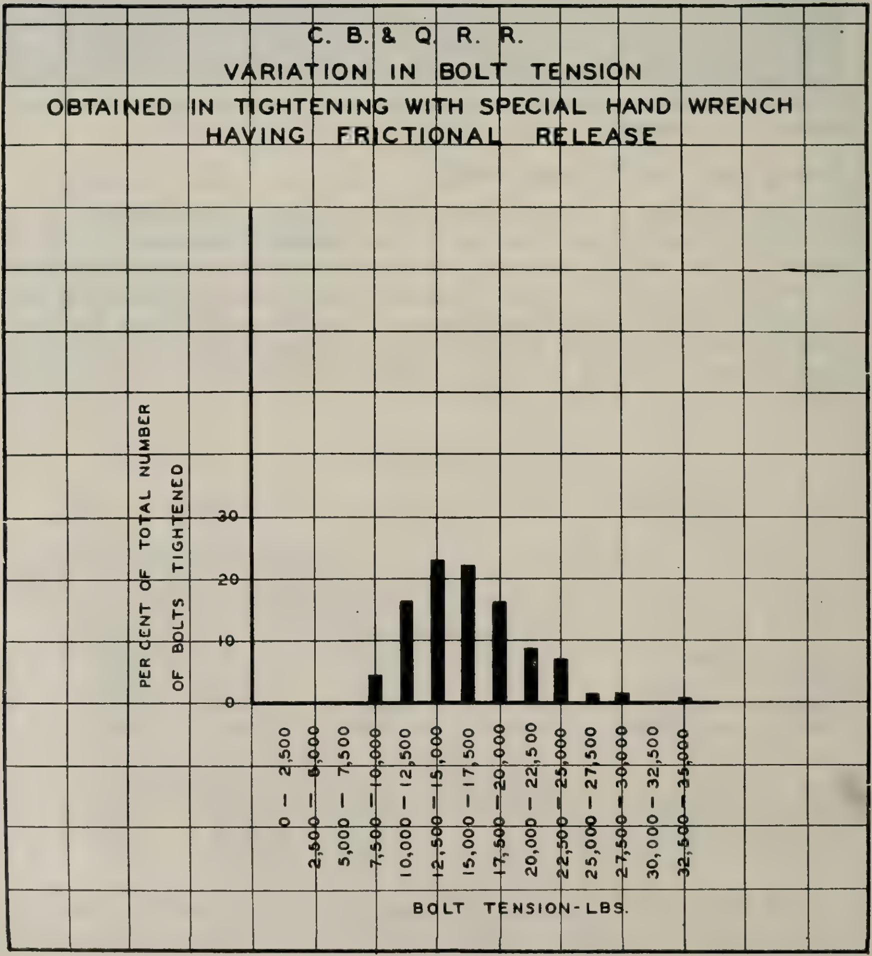


FIG. I

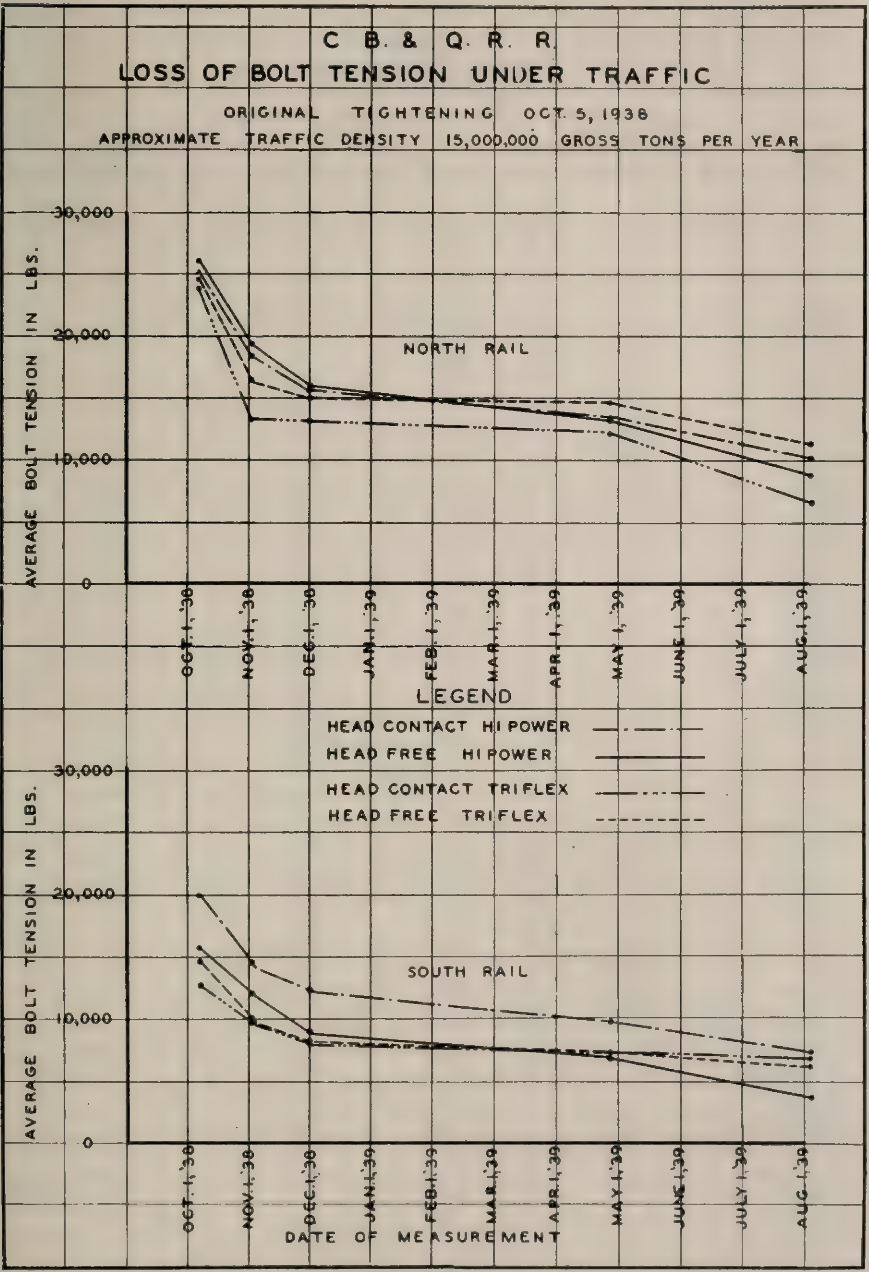

C. B. & Q. R. R.
LOSS OF BOLT TENSION UNDER TRAFFIC
ORIGINAL TIGHTENING OCT. 5, 1938
APPROXIMATE TRAFFIC DENSITY 15,000,000 GROSS TONS PER YEAR
NORTH RAIL
SOUTH RAIL
AVERAGE BOLT TENSION IN LBS.
30,000
20,000
10,000
0
OCT. 1, '38
NOV. 1, '38
DEC. 1, '38
JAN. 1, '39
FEB. 1, '39
MAR. 1, '39
APR. 1, '39
MAY 1, '39
JUNE 1, '39
JULY 1, '39
AUG. 1, '39
LEGEND
HEAD CONTACT HI POWER
HEAD FREE HI POWER
HEAD CONTACT TRIFLEX
HEAD FREE TRIFLEX
DATE OF MEASUREMENT

FIG. 2

Table 2
JOINT GAP MEASUREMENTS
C B & Q RR Test Installation

	SOUTH RAIL					NORTH RAIL			
	Joint Gap in Inches					Joint Gap in Inches			
Joint No.	10-7-38	11-30-38	2-25-39	8-4-39	Joint No.	10-7-38	11-30-38	2-25-39	8-4-39
1	.00	.24	.44	.00	2	.13	.24	.33	.00
3	.08	.26	.38	.00	4	.00	.06	.12	.00
5	.00	.07	.37	.00	6	.09	.16	.28	.00
7	.00	.13	.22	.00	8	.00	.36	.44	.00
9	.00	.10	.22	.00	10	.04	.09	.27	.00
11	.19	.22	.30	.00	12	.08	.10	.28	.00
13	.00	.16	.32	.00	14	.10	.32	.44	.00
15	.00	.25	.34	.00	16	.06	.32	.41	.00
17	.04	.21	.25	.00	18	.00	.04	.06	.00
19	.00	.13	.21	.00	20	.00	.01	.09	.00
21	.16	.30	.40	.00	22	.05	.06	.19	.00
23	.00	.07	.10	.00	24	.07	.21	.29	.00
25	.13	.20	.27	.00	26	.00	.19	.31	.00
27	.04	.22	.30	.00	28	.00	.15	.28	.00
29	.06	.22	.30	.00	30	.00	.27	.37	.00
31	.07	.16	.27	.00	32	.00	.19	.29	.00
33	.00	.14	.26	.00	34	.00	.21	.34	.00
35	.00	.25	.35	.00	36	.00	.17	.35	.00
37	.12	.33	.38	.00	38	.00	.21	.30	.00
39	.03	.32	.30	.00	40	.01	.38	.44	.00
41	.00	.13	.31	.00	42	.01	.32	.39	.00
43	.12	.20	.30	.00	44	.06	.07	.11	.07
45	.00	.00	.10	.00	46	.00	.08	.17	.00
47	.00	.03	.16	.00	48	.03	.05	.08	.00
49	.26	.27	.28	.11	50	.10	.17	.22	.12
51	.00	.00	.15	.00	52	.08	.06	.14	.10
53	.08	.07	.15	.00	54	.11	.13	.14	.11
55	.03	.04	.11	.00	56	.00	.15	.33	.00
57	.00	.01	.11	.00	58	.00	.00	.06	.00
59	.00	.07	.20	.00	60	.00	.00	.10	.00
61	.25	.10	.14	.00	62	.00	.03	.12	.00
63	.00	.26	.37	.00	64	.00	.12	.26	.00
65	.10	.36	.42	.00	66	.00	.31	.45	.00
67	.05	.05	.40	.00	68	.00	.20	.29	.00
69	.06	.15	.14	.00	70	.00	.03	.33	.00
71	.08	.08	.20	.03	72	.00	.08	.14	.00
73	.04	.03	.10	.03	74	.03	.00	.24	.00
75	.09	.04	.29	.00	76	.00	.03	.12	.00
77	.12	.18	.06	.00	78	.00	.17	.15	.00
79	.03	.03	.35	.00					
Total Gap	2.23	6.08	10.32	.17		1.05	5.74	9.72	0.40
Correction for End Movement	.00	.69	-.31	.44		.00	.57	.06	.25
Net	2.23	6.77	10.01	.61		1.05	6.31	9.78	0.65
Temp.	70°	33°	13°	115°		70°	33°	13°	115°

Expansion Movements

Joint gap openings were measured with a taper gage at various times. The results are given in Table 2. It is interesting to make a comparison of the measured change in length of the rail between the 13 deg. F. and 115 deg. F. rail temperature readings with the calculated change in length of an equivalent length of rail free of any restraint to its expansion movements.

Length of rail—18,720 in.

Temperature change—102 deg. F.

Theoretical change in length for 102 deg. F. temperature change = 102 × 18,720 × 0.0000065 = 12.40 in.

South Rail:

February 25, 1939—Net total joint gaps = ... 10.01 in.
August 4, 1939—Net total joint gaps = ... 0.61 in.

Actual change in rail length .... 9.40 in.
Change prevented by restraining forces 12.40 — 9.40 = ... 3.00 in.

$$\text{Restraining force} = \frac{3.00 \times 30{,}000{,}000 \times 12.82}{18{,}720} = 61{,}600 \text{ lb.}$$

Assuming that the principal restraining force is the joint restraint or the frictional resistance offered by the joint bars to the rail slipping within them and further that the joint restraints to contraction movement in the winter and expansion movement in the summer are equal, then the joint restraint would be 30,800 lb.

North Rail:

February 25, 1939—Net total joint gap = ... 9.78 in.
August 4, 1939—Net total joint gap = ... 0.65 in.

Actual change in length of rail = ... 9.13 in.
Restrained change in length = ... 3.27 in.

$$\text{Restraining force} = \frac{3.27 \times 30{,}000\,000 \times 12.82}{18{,}720} = 67{,}200 \text{ lb.}$$

Joint restraint—33,600 lb.

Laboratory experiments have shown that the frictional resistance of joint bars to rail movement is approximately equal to the sum of the bolt tensions for the bolts in one rail end. An average bolt tension of 10,000 lb. in six-hole joints would indicate a frictional resistance or joint restraint of 30,000 lb.

C. M. St. P. & P. R. R. Test Installation

The test installation on the Milwaukee Railroad near Winona, Minn., was described in last year's report. This test section is approximately ¼ mile in length. The rail is 112 lb. with 6-hole, toeless joint bars and one-inch track bolts without spring washers.

Uniformity of Bolt Tension Obtained in Tightening

On December 1, 1938, joints 1–17, inclusive, on the south rail were tightened with a Raco power wrench. The three bolts of each joint with the nuts on the outside were loosened and "no load" measurements of bolt length made with the bolt tension extensometer. The weight on the weighing lever of the Raco wrench was then adjusted to give a bolt tension of approximately 15,000 lb. as indicated by bolt extensometer measurements on three tightened bolts. It was found necessary to place the weight at the lowest bolt tension position on the graduated scale of the machine, whereas, according to the markings on the scale the weight should have been near the outer end to give 15,000 lb. bolt tension. The three loosened bolts on each joint were tightened. Next, the

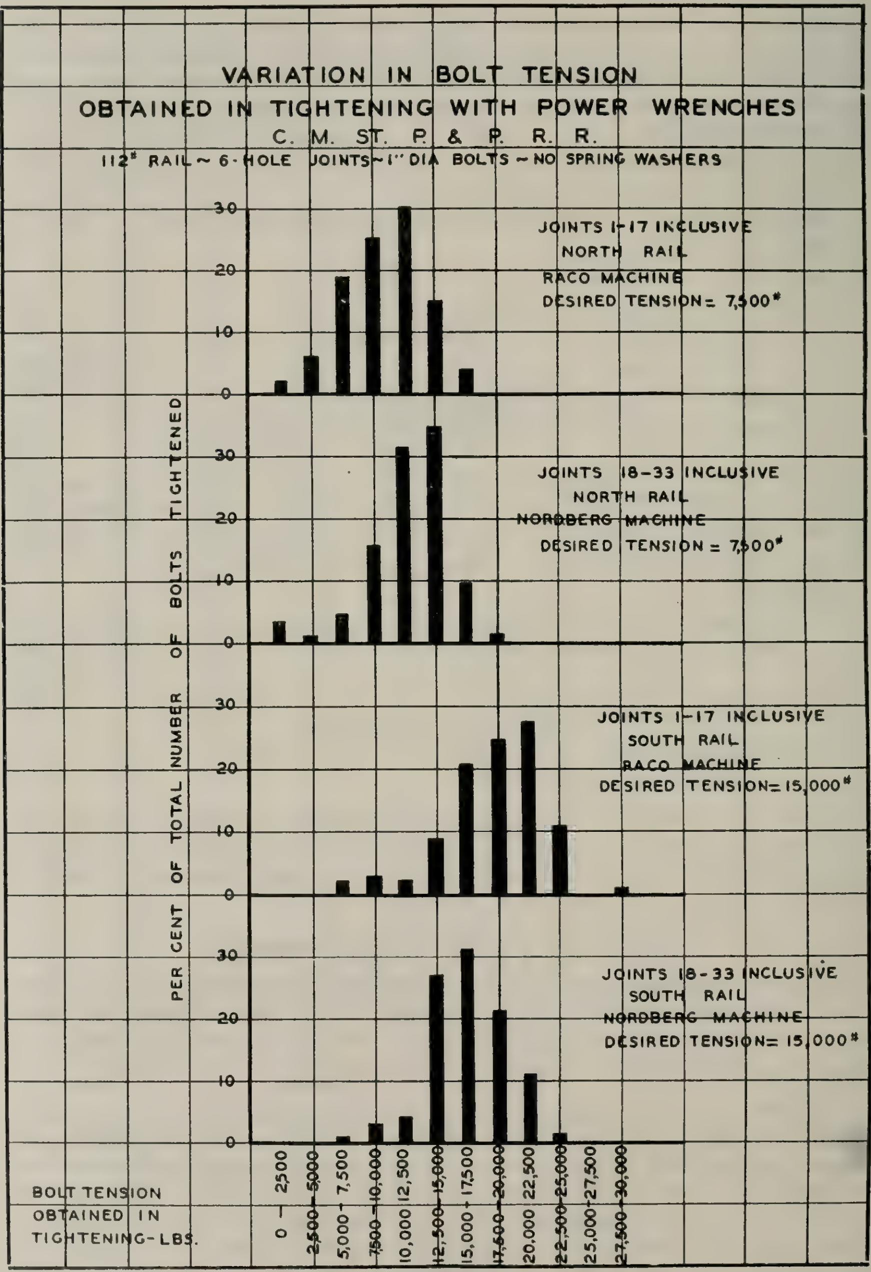

VARIATION IN BOLT TENSION
OBTAINED IN TIGHTENING WITH POWER WRENCHES
C. M. ST. P. & P. R. R.
112# RAIL ~ 6-HOLE JOINTS ~ 1" DIA BOLTS ~ NO SPRING WASHERS
JOINTS 1-17 INCLUSIVE
NORTH RAIL
RACO MACHINE
DESIRED TENSION = 7,500#
JOINTS 18-33 INCLUSIVE
NORTH RAIL
NORDBERG MACHINE
DESIRED TENSION = 7,500#
JOINTS 1-17 INCLUSIVE
SOUTH RAIL
RACO MACHINE
DESIRED TENSION = 15,000#
JOINTS 18-33 INCLUSIVE
SOUTH RAIL
NORDBERG MACHINE
DESIRED TENSION = 15,000#
PER CENT OF TOTAL NUMBER OF BOLTS TIGHTENED
30
20
10
0
BOLT TENSION
OBTAINED IN
TIGHTENING-LBS.
0 - 2,500
2,500-5,000
5,000-7,500
7,500-10,000
10,000-12,500
12,500-15,000
15,000-17,500
17,500-20,000
20,000-22,500
22,500-25,000
25,000-27,500
27,500-30,000

FIG. 3

other three bolts of each joint having the nuts on the inside were loosened and "no load" measurements made. These bolts were then tightened with the Raco wrench and measurements made to determine the applied bolt tension on all six bolts of each joint.

The same procedure was followed on joints 1–17, inclusive, on the north rail. It was desired on this rail, however, to obtain a bolt tension of approximately 7,500 lb. Accordingly, the weight was entirely removed from the weighing arm of the Raco machine leaving only the weight of the arm itself to regulate the "kickoff". "No load" measurements and measurements on the tightened bolts were made with the bolt tension extensometer to determine the tension applied.

Joints 18 to 34 on the south rail were tightened with a Nordberg machine in the same manner. Since there was no indication on this machine of the bolt tension setting of the 'kickoff", it was necessary to regulate this entirely by means of readings taken on tightened bolts with the bolt tension extensometer. The kickoff was set for approximately 15,000 lb. tension as indicated by readings taken on three bolts.

Table 3

Bolt Tensions Obtained with Successive "Kick-offs"

Raco Wrench Bolt No.95		Nordberg Wrench Bolt No.208	
Tightening No.	Bolt Tension Obtained	Tightening No.	Bolt Tension Obtained
1	15,100	1	17,800
2	20,300	2	19,800
3	19,200	3	18,700
4	18,600	4	19,900
5	16,500	5	13,300
6	19,400	6	16,000
7	17,900	7	17,200
8	18,800	8	16,400
9	19,600	9	17,800
10	21,200	10	19,600
Average	18,660	Average	17,640
Maximum Variation from Average	-19%, + 14%		-25%,+ 13%

Joints 18 to 33, inclusive, on the north rail were tightened in the same manner with the Nordberg machine, but with the "kickoff" adjusted to give approximately 7,500 lb. bolt tension as indicated by bolt extensometer readings. Fig. 3 shows the uniformity of tightening obtained in these four separate tests.

The difference between the mean bolt tension obtained on each test and the desired tension is due to error in setting the "kickoff". The variation between individual values of bolt tension obtained within each test is due to variation in the "kickoff" of the machine and in the frictional resistance of the track bolt nuts. These track nuts were manufactured in accordance with AREA specifications for wrench turn fit. However, with the machines set for the lower bolt tension value of 7,500 lb., there were a few bolts on each of the two tests which could not be brought up to the face of the joint bar because of excessive thread friction on these individual bolts.

Table 4
BOLT TENSION MEASUREMENTS
C M St.P & P RR Test Installation

	NORTH RAIL			SOUTH RAIL		
	Average Bolt Tension Per Joint- Lbs.			Average Bolt Tension Per Joint- Lbs.		
Jt. No.	Applied 12-2-38	Remaining 6-30-39	Loss	Applied 12-2-38	Remaining 6-30-39	Loss
1	10,660	7,910	2,750	15,980	7,080	8,900
2	-	-	-	-	-	-
3	9,270	3,110	6,160	19,580	12,980	6,600
4	9,450	6,120	3,330	18,430	8,460	9,970
5	11,320	6,690	4,630	17,400	11,230	6,170
6	9,200	6,350	2,850	19,220	13,720	5,500
7	10,320	3,490	6,830	15,570	5,840	9,730
8	11,550	8,940	2,610	19,570	11,420	8,150
9	8,630	3,780	4,850	23,200	12,530	10,670
10	10,050	7,570	2,480	16,620	11,530	5,090
11	13,040	8,520	4,520	20,400	12,300	8,100
12	10,520	5,140	5,380	19,160	11,230	7,930
13	10,050	8,070	1,980	16,530	6,750	9,780
14	8,880	6,710	2,170	19,580	13,880	5,700
15	-	-	-	20,150	9,800	10,350
16	7,490	3,370	4,120	16,700	10,100	6,600
17	10,150	1,950	8,200	18,910	11,980	6,930
18	10,600	8,570	2,030	15,060	7,480	7,580
19	11,320	6,000	5,320	16,680	10,710	5,970
20	10,430	5,020	5,410	18,300	7,780	10,520
21	7,180	4,810	2,370	18,560	10,270	8,290
22	10,890	8,630	2,260	16,650	10,770	5,880
23	10,480	8,190	2,290	14,380	5,180	9,200
24	13,120	9,160	3,960	16,680	11,850	4,830
25	11,750	6,520	5,230	15,600	10,370	5,230
26	11,200	5,270	5,930	14,820	8,240	6,580
27	13,670	11,720	1,950	12,750	6,300	6,450
28	11,550	7,120	4,430	14,820	7,210	7,610
29	8,650	2,410	6,240	16,070	9,150	6,920
30	14,150	7,090	7,060	15,430	5,710	9,720
31	11,500	6,830	4,670	17,100	9,380	7,720
32	14,100	5,770	8,330	17,190	9,330	7,860
33	14,720	9,200	5,520	15,350	9,120	6,230
34				16,170	8,560	7,610
Total	335,890	200,030	135,860	568,610	318,240	250,370
Ave.	10,835	6,452	4,383	17,231	9,644	7,587
% Loss of Original Tension			41%			44%

To get a check on the variation of the "kickoff" of the machine, a bolt was selected with a comparatively free turning nut. This bolt was then successively tightened and loosened ten times with the machine and bolt tension measurements made for each tightening with the results shown in Table 3.

Loss of Bolt Tension Under Traffic

The bolts, having been tightened as above described on December 1 and 2, 1938, were left undisturbed until June 30, 1939, on which date the bolt tension was again measured with the results shown in Table 4.

Table 5
JOINT GAP MEASUREMENTS
C M St P & P RR Test Installation

NORTH RAIL			SOUTH RAIL		
Joint No.	Joint Gap in Inches 12-2-38	6-30-39	Joint No.	Joint Gap in Inches 12-2-38	6-30-39
1	.03	.01	1	-	-
2	.19	.03	2	.19	.01
3	.01	.01	3	.03	.02
4	.06	.00	4	.04	.02
5	.00	.01	5	.10	.05
6	.09	.07	6	.03	.01
7	.08	.01	7	.28	.00
8	.26	.04	8	.18	.10
9	.09	.02	9	.09	.00
10	.27	.08	10	.11	.00
11	.17	.02	11	.01	.01
12	.03	.0	12	.18	.00
13	.08	.04	13	.33	.01
14	.26	.02	14	.01	.0
15	.11	.02	15	.04	.0
16	.19	.00	16	.08	.01
17	.17	.01	17	.13	.05
18	.10	.01	18	.28	.00
19	.10	.03	19	.07	.00
20	.26	.00	20	.16	.00
21	.05	.02	21	.12	.00
22	.20	.06	22	.25	.02
23	.23	.07	23	.26	.01
24	.27	.16	24	.16	.02
25	.25	.10	25	.11	.01
26	.21	.02	26	.23	.0
27	.14	.10	27	.15	.01
28	.09	.00	28	.06	.0
29	.31	.02	29	.16	.01
30	.22	.03	30	.14	.00
31	.25	.04	31	.34	.05
32	.13	.00	32	.15	.0
33	.19	.02	33	.15	.0
			34	-	-
Total	5.09 in.	1.07 in.		4.62 in.	.42 in.
End Movement Correction	.00 in.	-.19 in.		.00	-.50 in.
Net Total Gap	5.09 in.	.88 in.		4.62 in.	-.08 in.
Rail Temperature	37°	85°		37°	85°

Table 6
LOSS IN BOLT TENSION ON D. & R.G.W. TEST
(Values given are averages per joint per bolt in lbs.)

NORTH RAIL				SOUTH RAIL			
Joint No.	9-7-38 to 11-9-38	9-7-38 to 5-3-39	9-7-38 to 11-9-39	Joint No.	9-7-38 to 11-9-38	9-7-38 to 5-3-39	9-7-38 to 11-9-39
				TANGENT			
1	8,780	12,950	17,420	-	-	-	-
2	8,770	17,320	21,500	26	8,510	16,750	20,850
3	13,210	15,980	21,600	27	8,280	13,700	17,600
4	13,130	12,560	19,900	28	5,220	8,270	14,000
5	16,280	17,430	25,100	29	12,570	11,030	17,800
6	6,970	6,870	10,560	30	9,270	9,040	17,050
7	11,000	15,050	21,400	31	5,420	5,050	12,650
8	17,680	24,450	30,700	32	6,470	5,900	11,800
9	15,380	20,850	29,700	33	9,690	13,100	15,350
10	16,450	20,650	26,650	34	4,950	7,130	13,400
11	18,460	25,100	32,700	35	11,300	10,280	16,000
12	22,500	29,500	33,300	36	6,530	3,140	11,900
13	16,820	21,050	28,100	37	6,530	8,570	18,150
14	19,850	23,300	28,600	38	7,810	8,000	18,550
15	3,055	7,720	12,260	39	9,780	10,170	16,750
16	14,030	21,600	34,700	40	8,220	14,270	20,900
17	8,720	14,370	18,750	41	7,930	7,050	10,550
18	16,000	22,750	28,250	42	9,220	8,080	10,450
19	21,250	29,250	30,700	43	13,300	16,530	20,250
20	16,780	28,450	33,600	44	5,930	10,950	11,800
AVE.	14,280	19,330	25,300		8,220	9,770	16,000
				CURVE			
21	20,950	30,500	37,000	45	11,250	16,160	16,450
22	11,430	18,650	20,500	46	10,230	9,230	14,250
23	10,650	17,030	26,000	47	8,670	10,470	14,450
24	20,000	22,100	28,100	48	9,720	14,750	18,750
25	16,350	18,080	25,000	49	11,860	12,660	15,130
				50	10,360	10,750	16,450
AVE.	15,850	21,300	27,300		10,430	12,600	15,030
GR.AVE.	14,610	19,700	25,700		8,770	10,440	15,550

At the time of making the June 30, 1939 measurements, three bolts were found loose on the north rail and three loose on the south rail. The nuts were still on the bolts, however.

After completing the bolt tension measurements, the bolts were retightened by hand wrench to restore the bolt tensions to approximately 7,500 lb. on the north rail and 15,000 lb. on the south rail. Bolt extensometer readings were taken on the tightened bolts from which the bolt tension loss will be again determined after an interval of time.

The joint gaps were measured at the time of both series of bolt tension readings with the results shown in Table 5.

It will be noted that joints 1, 3, 5, 12 and 21 on the north rail and joints 3, 4, 6 11 and 14 on the south rail had substantially the same openings at both series of readings. There were no joint gaps sufficiently wide to indicate bent bolts from rail contraction in the December 2, 1938 measurements.

D. & R. G. W. Ry. Test Installation

The rail was laid for this test installation on the D. & R. G. W. Ry. main line near Glenwood Springs, Colo., on September 7, 1938 as described in last year's report. The

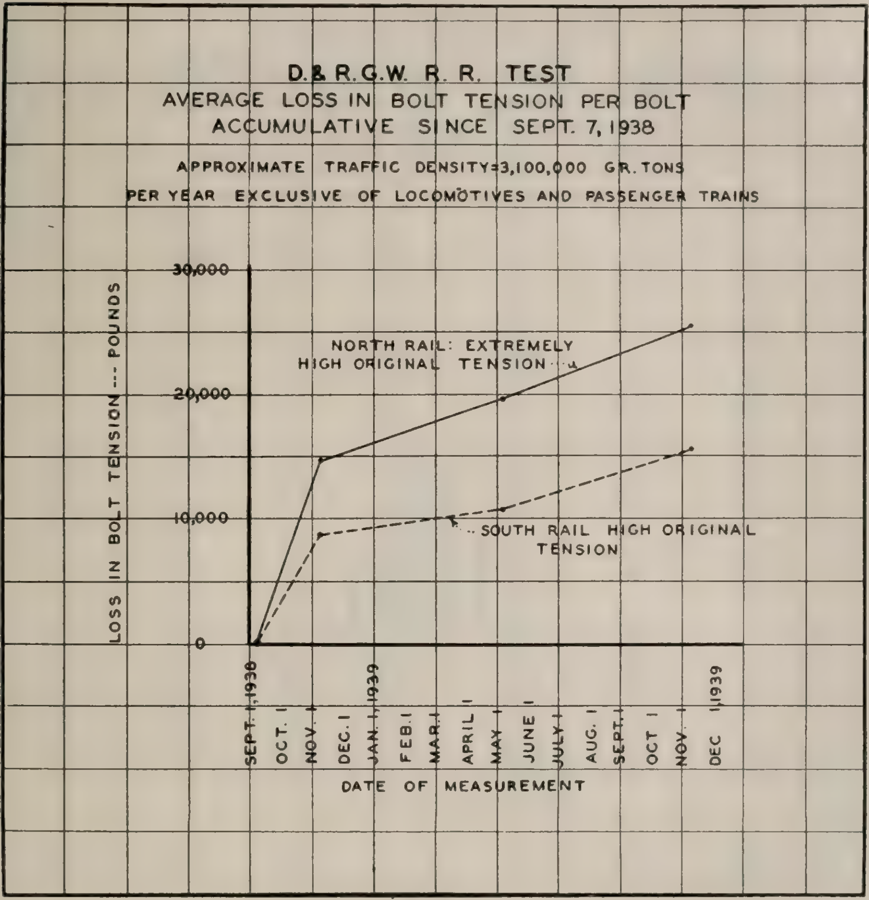


FIG 4

rail is 131 lb., with 4-hole toeless joint bars, 1⅛ inch heat-treated bolts and National grooved spring washers. At the time the installation was laid, the bolts on the north rail were tightened with a Nordberg power wrench, and the bolts on the south rail were tightened by hand with a 48-in. wrench. The bolts were tightened so tightly that accurate data on the bolt tension originally applied will not be available from the bolt extensometer measurements until the bolts are loosened and the permanent set determined. This has not been done to date because there was still sufficiently high tension remaining on the bolts on November 9, 1939—one year and two months after the original tightening. The bolts have not been disturbed since they were first tightened in connection with the rail laying. The average tension applied on the north rail with the power wrench was probably between 50,000 to 60,000 lb. and on the south rail with the hand wrench, 25,000 to 30,000 lb.

Table 6 gives the bolt tension loss at three successive periods of measurement following the bolt tension measurements obtained at the time the rail was laid. Fig. 4 shows the same information in graphical form.

Table 7
JOINT GAP MEASUREMENTS ON D&RGW TEST

NORTH RAIL				SOUTH RAIL			
Joint No.	Joint Gap in Inches 11-9-38	5-3-39	11-9-39	Joint No.	Joint Gap in Inches 11-9-38	5-3-39	11-9-39
				TANGENT			
1	.00	.00	.02				
2	.11	.00	.04	26	.06	.00	.06
3	.00	.00	.00	27	.04	.00	.00
4	.02	.00	.00	28	.04	.00	.00
5	.23	.00	.23	29	.02	.00	.02
6	.06	.00	.03	30	.05	.00	.13
7	.00	.00	.02	31	.26	.10	.08
8	.12	.02	.25	32	.14	.00	.09
9	.02	.00	.12	33	.06	.00	.06
10	.13	.02	.19	34	.35	.11	.20
11	.20	.04	.17	35	.18	.00	.09
12	.06	.00	.08	36	.00	.00	.02
13	.14	.08	.16	37	.01	.00	.09
14	.22	.06	.47	38	.03	.02	.16
15	.25	.02	.13	39	.23	.08	.16
16	.21	.09	.22	40	.33	.11	.28
17	.01	.00	.02	41	.26	.07	.20
18	.26	.03	.21	42	.18	.16	.06
19	.17	.03	.06	43	.17	.15	.11
20	.04	.00	.09	44	.02	.02	.04
				6° CURVE			
21	.14	.00	.12	45	.35	.26	.26
22	.01	.00	.00	46	.36	.12	.34
23	.11	.03	.15	47	.29	.15	.27
24	.01	.00	.02	48	.33	.20	.12
25	.04	.00	.28	49	.43	.10	.20
				50	.29	.14	.03
Total Gap End Movement	2.56	.42	3.08		4.48	1.79	3.07
Correction	.00	-.56	-.94		-.25	-.19	-.31
Net Total Gap	2.56	-.14	2.14		4.23	1.60	2.76
Rail Temperature	30°	65°	*45°		30°	65°	*45°

(*)Estimated not measured.

It will be noted from these data that there was a very rapid drop in bolt tension in the two months' interval immediately following the rail laying. From then on the rate of decrease has been much less. It appears that the rate of decrease is also less on the south rail on which the bolts were not given as high an original tension as on the north rail.

The total traffic over this single track main line was approximately 3,100,000 gross tons from November 1, 1938 to November 1, 1939, freight only, excluding locomotives and passenger traffic.

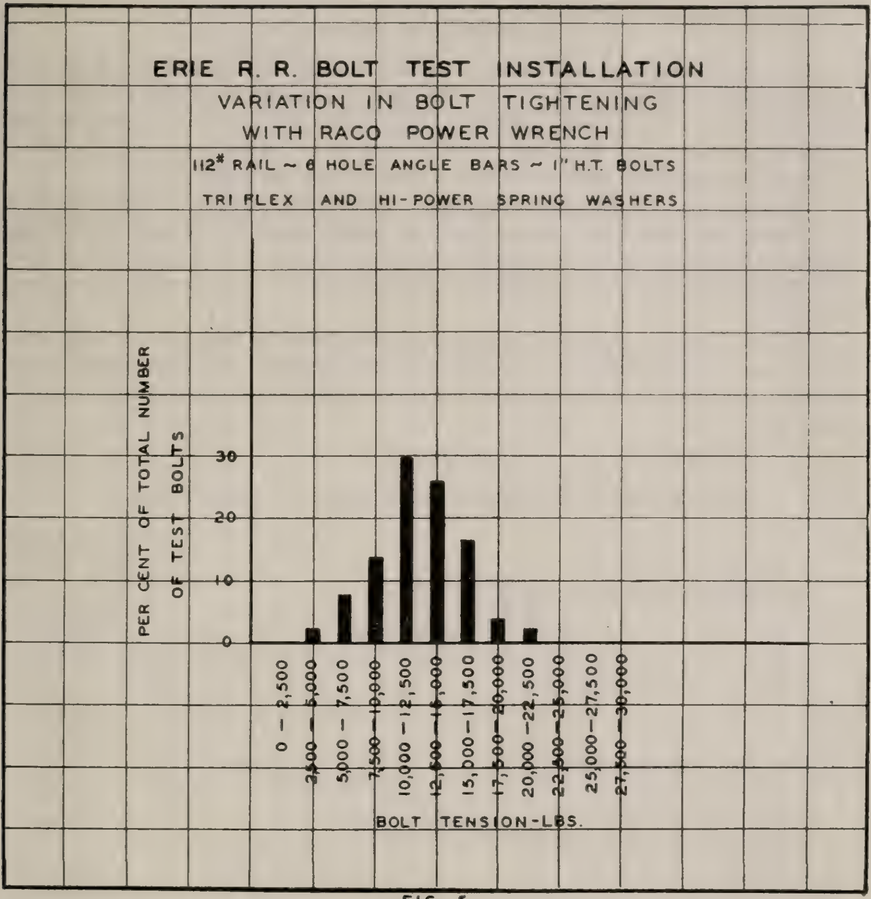


FIG. 5

The joint gaps were not measured at the time the rail was laid. Joint gap measurements were taken at the time the later bolt tension measurements were made and these are shown in Table 7.

It will be noted in Table 7 that seven joints on the north rail and three joints on the south rail show little change in gap at the three periods of measurements. At joint 14 on the north rail at the time of the November 9, 1939 measurements, the joint bolts have apparently been slightly bent by the contraction forces on the rail as the clearances provided between joint and rail drillings and bolt diameter only provide for a maximum opening of 0.38 ins. This same condition to a lesser extent will be noted at joint 49 on the south rail at the November 9, 1938 measurements.

The end movement corrections shown are the amounts that the rail at the extremities of the test section have moved with reference to markers fixed in the roadbed. The theoretical expansion of the rail for the temperature changes indicated, if free of restraint, may be compared with the actual expansion as indicated by the relative net joint gaps with the rail subjected to the joint bar friction and other restraints actually existing in the track.

Test Installation on the Erie R. R.

On July 19, 1939, a bolt tension test was installed on the Erie Railroad at M.P. 223 near Griffith, Ind. New 112-lb. rail was laid with 6-hole angle bars and one-inch heat-treated bolts. The test installation consisted of 8 joints on the north rail and 10 joints on the south rail, a total of 18 joints and 105 test bolts. Triflex springs were placed on 33 of the test bolts and Hi-Power spring washers on the remainder.

The bolts were all tightened with a Raco power wrench, Model 2L. The weight on the weighing arm was placed at the 15,000 lb. tension mark on the scale for low gear operation. The bolts were then tightened with the machine in low gear. Fig. 5 shows the uniformity of tightening obtained as determined by bolt tension extensometer readings.

Table 8 shows a check test was made to determine the conformity of the actual bolt tension obtained with the scale marked on the weighing arm of the power wrench. Measurements were made on Bolts 2, 3 and 4—Joint 1-N—Chrome Hi-Power spring washers.

TABLE 8

Check Test to Determine Conformity of Actual Tension

Bolt No.	*Actual Tension Obtained—Lb.*
Low Gear—Weight set at 15,000.	
2	19,800
3	20,600
4	18,100
High Gear—Weight set at 9,000.	
2	6,600
3	7,400
4	4,100
High Gear—Weight set at 15,000.	
2	14,000
3	12,000
4	9,100
High Gear—Weight set at End of Arm.	
2	16,500
3	13,200
4	10,700
Low Gear—Weight set at 20,000.	
2	23,000
3	24,000
4	21,200

It will be noted that with low gear operation the bolt tension obtained was somewhat in excess of the weighing arm markings, whereas, in high gear the bolt tension obtained was less than the weighing arm markings. Generally, the conformity was reasonably good.

Test Installation on the Pennsylvania Railroad

On August 26, 1939, a bolt tension test was installed on the Pennsylvania Railroad track No. 1 near Birmingham, Pa. This track carries very high traffic density, approximately 50,000,000 gross tons annually. The rail is 152-lb. Pennsylvania section, with 6-hole toeless joint bars, 1⅛-in. bolts, and spring washers. The bolts were especially selected for the test to insure that the nut could be freely turned by hand over the entire length of the threaded portion of the bolt.

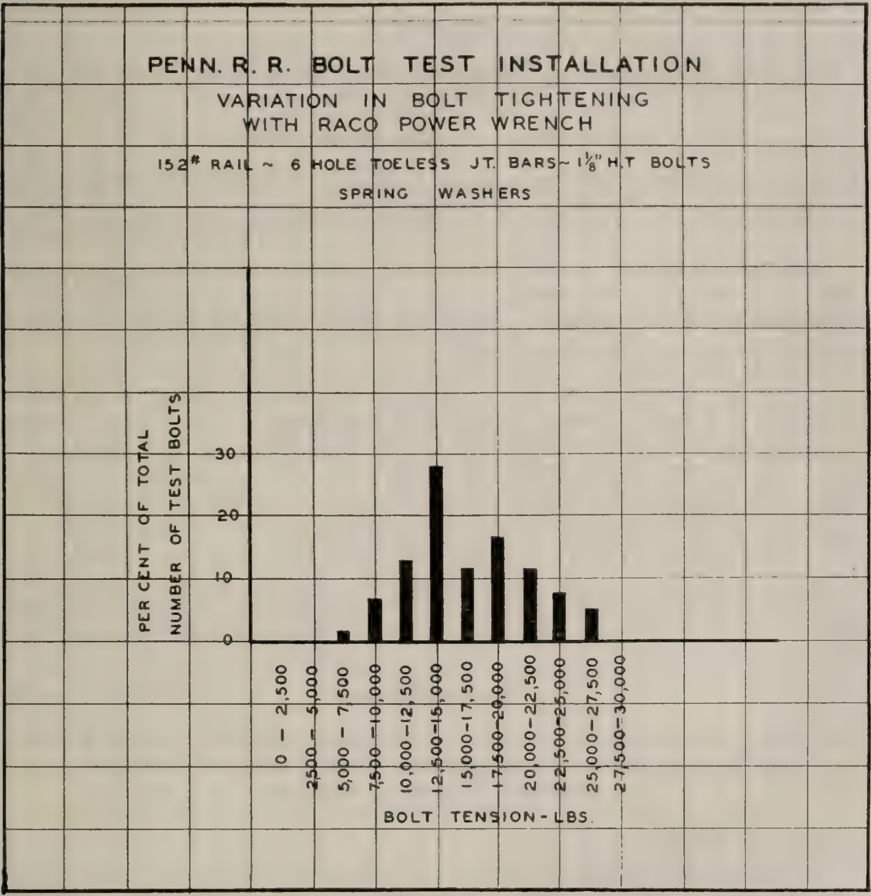


FIG. 6

The test bolts (103 in number) were tightened with a Raco power wrench excepting 24 which had to be tightened by hand wrench because of lack of clearance for the machine with the special type of joint tie plate used. Fig. 6 shows the uniformity of tightening obtained as determined by bolt tension extensometer measurements. It will be noted that considerable variation in bolt tension resulted even though free-turning nuts were used on the bolts.

This rail was laid in the early part of August, 1939, and given two follow-up tightenings before the test bolts were installed. Only three bolts were taken out of a joint at a time while installing the test bolts, thereby maintaining the joint bar "seat". Bolt tension readings were repeated on October 10, 1938 at which time it was found that the average bolt tension per bolt had decreased 1,340 lb. from the original applied tension.

The report is presented as information with the recommendation that the subject be continued.

Appendix J

(11) Prevention of Damage Due to Brine Drippings on Track Structures

Collaborating with Mechanical Division

G. M. Magee (chairman, subcommittee), W. G. Arn, C. W. Baldridge, R. W. E. Bowler, H. R. Clarke, F. W. Hillman, C. T. Jackson, J. de N. Macomb, K. R. McLennan, W. A. Murray, G. L. Sitton, C. R. Strattman, H. von Schrenk, J. G. Wishart.

On Tuesday, January 17, 1939, a meeting was held at the Association offices in Chicago for the purposes of discussing the results of the tests made to date in the study of "Corrosion from Brine Drippings", and to decide upon a plan for continuing the research work on this matter. Those present were:

H. G. Miller, Engr. of Tests, C. M. St. P. & P. R. R.
O. T. Rees, Asst. Engr. of Tests, A. T. & S. F. Ry.
Walter Leaf, Research Technician, D. & R. G. W. Ry.
A. S. Perry, Chief Chemist, C. & O. Ry.
W. G. Arn, Chairman, Joint Committee
C. W. Baldridge, Asst. Engr., A. T. & S. F. Ry.
G. M. Magee, Research Engineer, Engr. Div. AAR

After extended considerations, the following procedure for continuing this work was decided upon, with the thought that it would be the most effective in securing the desired results.

Test Procedure

PROCEDURE FOR CONTINUATION OF TESTS TO DETERMINE THE MOST SUITABLE INHIBITOR TO BE ADDED WITH SALT IN ICING REFRIGERATOR CARS FOR PREVENTING CORROSION FROM BRINE DRIPPINGS

Method of Testing

It was decided to change the form of test from that previously used. Instead of the large, rectangular, bent test specimen used in the previous tests, a smaller flat, circular specimen will be used constructed in two parts, so the top and bottom surface corrosion may be measured separately. Also, it was desired to apply the brine in a measured amount over the entire surface of the specimen rather than to drip it on only a small portion of the surface.

Test Specimen

In order that all test specimens shall be from the same piece of steel, the necessary number of test specimen blanks will be prepared at one source and furnished each laboratory. The blanks will be approximately 2 in. in diameter and ⅛ in. thick. Two blanks will be required to make one test specimen; they will be placed together flatwise and thoroughly sealed together around their entire circumference by coating their edges with paint. However, before the two blanks comprising each test specimen are sealed together, each blank should be stamped with its specimen test number on the face that will be exposed and the letter "T" or "B" designating top or bottom surface respectively. The exposed surface of each blank should then be belt polished, the blank pickled, then accurately weighed, and the weight recorded.

Test Apparatus

Sufficient separate containers for the various solutions are necessary and a means of conveying the specified amount of solution from the containers to the test specimen. While the test is in progress, each test specimen should rest in the same location on a creosoted plank.

Temperature

The test will, of course, be carried out within the laboratory where the temperature will be reasonably uniform.

Test Procedure

After the test specimens have been prepared and placed in their assigned locations on the creosoted plank, they are ready for the brine applications. Each morning an application will be made as follows: First, specimen will be lifted, 1 ccm. of solution dropped on the plank within the area covered by the specimen, and the specimen then replaced. Second, 1 ccm. of solution will be dropped on the top surface of the specimen and then spread to cover the entire surface with a glass rod, but without disturbing the scaled surface with the rod. Each evening the application will be made only to the top surface of the specimen in the manner above outlined; not to the bottom surface.

Twice each week, each specimen will be taken to the sink and the soluble salts washed from its top and bottom surfaces with distilled water and a washing bottle.

Several combinations of corrodants and inhibitors will be tested. Also, each test specimen will be run in duplicate, one specimen to be checked each month for loss of weight, and the other to be checked *only* at the completion of the test.

Also, at each laboratory tests will be carried out with 10 percent salt solution and with one other salt solution as designated below:

Milwaukee Road—10 percent and saturated salt solution
D. & R. G. W.—10 percent and 20 percent salt solution
A. T. & S. F.—10 percent and 15 percent salt solution
C. & O.—10 percent and 5 percent salt solution

The percentage salt solution will mean the percent of salt in the entire solution; for example, a 10 percent salt solution will contain 10 grams of salt per 100 grams of salt solution.

Corrodants and Inhibitors to Be Tested

1. Distilled water.

2. Salt Solution.—One salt will be selected for use at all laboratories after a chemical analysis has been furnished of the rock salt available at each laboratory.

3. Salt solution plus 3.2 grams of sodium dichromate per liter plus sufficient S.S.C. to produce a Ph concentration of 8.0. A quantity of S.S.C. (sodium silicate compound) will be furnished each laboratory.

4. Salt solution plus 1.6 grams of sodium dichromate per liter plus sufficient S.S.C. to produce Ph concentration of 8.0.

5. Salt solution plus 0.8 grams of sodium dichromate per liter plus sufficient S.S.C. to produce Ph concentration of 8.0.

6. Salt solution plus 0.4 grams of sodium dichromate per liter plus sufficient S.S.C. to produce Ph concentration of 8.0.

7. Salt solution plus 1 gram per liter of S.S.C.

8. Salt solution plus 3 grams per liter of S.S.C.

MILWAUKEE LABORATORY
SATURATED SALT SOLUTION CORROSION TEST

Weight Loss in Grams							Corroding Solution And Inhibitors
Spec. No.	1st.30 day test	2nd.30 day test	3rd. 30 day test	Total	Spec. No.	90 day test	
1T	.560	.715	.592	1.867	1TX	1.634	Distilled Water
1B	.646	.704	.768	2.118	1BX	1.961	
E2T	.753	.715	.508	1.976	E2TX	2.253	Salt Solution
E2B	.400	.604	.524	1.528	E2BX	1.620	
E3T	.119	.075	.108	.302	E3TX	.133	Salt Sol. + 3.2 G/L Sodium Dichromate + 2.377 G/L S.S.C.
E3B	.204	.163	.136	.503	E3BX	.341	
E4T	.130	.178	.093	.401	E4TX	.764	Salt Sol. + 1.6 G/L Sodium Dichromate + 1.195 G/L S.S.C.
E4B	.219	.171	.170	.560	E4BX	.830	
E5T	.479	.440	.221	1.140	E5TX	1.499	Salt Sol. + 0.8 G/L Sodium Dichromate + 0.602 G/L S.S.C.
E5B	.387	.358	.305	1.050	E5BX	1.400	
E6T	.680	.680	.375	1.735	E6TX	2.159	Salt Sol. + 0.4 G/L Sodium Dichromate + 0.305 G/L S.S.C.
E6B	.487	.464	.418	1.369	E6BX	1.828	
E7T*	.930	.795	.790	2.515	E7TX	2.312	Salt Sol. + 1.0 G/L S.S.C.
E7B	.482	.502	.474	1.458	E7BX	1.629	
E8T*	.557	.512	.264	1.333	E8TX	1.971	Salt Sol. + 3.0 G/L S.S.C.
E8B	.410	.408	.426	1.244	E8BX	1.659	
E9T	.104	.076	.757	.511	E9TX	.106	Salt Sol. + 3.2 G/L Sodium Dichromate + 2.304 G/L Soda Ash
E9B	.127	.124	.168	.419	E9BX	.207	
E10T	.803	.690	.355	1.848	E10TX	2.032	Salt Sol. + 0.4 G/L Sodium Dichromate + 0.290 G/L Soda Ash
E10B	.401	.472	.375	1.248	E10BX	1.712	
E11T#	.910	.938	.618	2.466	E11TX	2.446	Salt Sol. + .04 G/L Mercoptobenzothiozole
E11B	.627	.740	.605	1.972	E11BX	1.644	
E12T#	.957	1.043	.573	2.573	E12TX	2.426	Salt Sol. + 1.0 G/L Quebracho
E12B	.416	.649	.500	1.565	E12BX	1.789	

* Heavy precipitate formed.
# Incompletely dissolved.

9. Salt solution plus 3.2 grams of sodium dichomate per liter plus sufficient soda ash to produce a Ph concentration of 8.0.

10. Salt solution plus 0.4 grams of sodium dichromate per liter plus sufficient soda ash to produce a Ph concentration of 8.0.

11. Salt solution plus 0.04 grams of mercoptobenzothiozole per liter.

12. Salt solution plus 1 gram quebracho per liter.

Numbering of Test Specimen

In view of the large number of test specimens to be used, the following method of numbering is suggested:

(I) Use the prefix

A for 5-percent salt solution.
B for 10-percent salt solution.
C for 15-percent salt solution.
D for 20-percent salt solution.
S for Saturated Salt Solution.

(II) Use next the number given above in the series 1 to 12 inclusive to designate the corrodant and inhibitor used.

MILWAUKEE LABORATORY
10 PERCENT SALT SOLUTION CORROSION TEST

Weight Loss in Grams							
Spec. No.	1st 30 day test	2nd 30 day test	3rd 30 day test	Total	Spec. No.	90 day test	Corroding Solution And Inhibitors
1T	.560	.715	.592	1.867	1TX	1.634	Distilled Water
1B	.646	.704	.768	2.118	1BX	1.961	
B2T	.925	1.013	.386	2.324	B2TX	2.616	Salt Solution
B2B	.708	.623	.502	1.833	B2BX	2.192	
B3T	.140	.076	.125	.341	B3TX	.111	Salt Sol. + 3.2 G/L Sodium Dichromate + 2.306 G/L S.S.C.
B3B	.222	.128	.199	.549	B3BX	.358	
B4T	.239	.115	.101	.455	B4TX	.172	Salt Sol. + 1.6 G/L Sodium Dichromate + 1.151 G/L S.S.C.
B4B	.391	2.271	.198	.745	B4BX	.448	
B5T	.544	.353	.165	1.062	B5TX	1.861	Salt Sol. + 0.8 G/L Sodium Dichromate + 0.578 G/L S.S.C.
B5B	.573	.459	.453	1.485	B5BX	1.388	
B6T	.789	.575	.304	1.668	B6TX	2.177	Salt Sol. + 0.4 G/L Sodium Dichromate + 0.293 G/L S.S.C.
B6B	.659	.571	.604	1.834	B6BX	1.709	
B7T*	.616	.663	.412	1.691	B7TX	2.383	Salt Sol. + 1.0 G/L S.S.C.
B7B	.669	.624	.621	1.914	B7BX	1.876	
B8T*	.343	.161	.318	.822	B8TX	1.019	Salt Sol. + 3.0 G/L S.S.C.
B8B	.560	.403	.602	1.565	B8BX	1.514	
B9T	.118	.061	.267	.446	B9TX	.205	Salt Sol. + 3.2 G/L Sodium Dichromate + 2.252 G/L Soda Ash
B9B	.211	.128	.233	.572	B9BX	.348	
B10T	.748	.791	.425	1.964	B10TX	2.056	Salt Sol. + 0.4 G/L Sodium Dichromate + 0.294 G/L Soda Ash
B10B	.565	.660	.671	1.896	B10BX	1.757	
B11T#	.927	1.069	.590	2.586	B11TX	2.574	Salt Sol. + .04 G/L Mercoptobenzothiozole
B11B	.658	.831	.747	2.236	B11BX	2.341	
B12T#	.837	.942	.585	2.364	B12TX	2.924	Salt Sol. + 1.0 G/L Quebracho
B12B	.707	.816	.868	2.391	B12BX	2.143	

* Heavy precipitate
# Incompletely dissolved

(III) Use next the letter "T" or "B" to show top or bottom blank of the test specimen.

(IV) Use last on the specimens to be run throughout the test and weight *only* at their completion the letter "X."

Thus a specimen blank numbered C9B would be the bottom blank of the specimen for 15 percent solution plus 3.2 grams sodium dichromate per liter plus soda ash.

A specimen blank numbered 1TX would be the top blank of the distilled water specimen which is not to be cleaned and weighed until the tests are completed.

Duration of Tests

Checks on the weight loss of one series of specimens (not marked with an "X") will be made at monthly intervals for as long as it is desired to run the tests. Weight loss on the other series (marked "X") will not be determined until the test is completed.

Weighing Specimens and Reporting Results

It is recommended that the specimens be cleaned of rust in hot 10 percent ammoniacal solution of ammonium citrate before weighing to determine the corrosion loss. The corrosion loss will be reported in grams loss of weight of the specimen.

D & RGW LABORATORY
10 PERCENT SALT SOLUTION CORROSION TEST

Weight Loss in Grams							Corroding Solution And Inhibitors
Spec. No.	1st.30 day test	2nd.30 day test	3rd.30 day test	Total	Spec. No.	90 day test	
1T	.1523	.1093	.1107	.3723	1TX	.3054	Distilled Water
1B	.1746	.1582	.1316	.4644	1BX	.5219	
B2T	.3702	.3018	.3745	1.0465	B2TX	1.7014	Salt Solution
B2B	.5604	.4897	.3371	1.3872	B2BX	2.3067	
B3T	.0252	.0202	.0397	.0851	B3TX	.0705	Salt Sol. + 3.2 G/L Sodium Dichromate + 4.687 G/L S.S.C.
B3B	.0452	.0550	.0420	.1422	B3BX	.1437	
B4T	.0725	.0307	.0347	.1379	B4TX	.1443	Salt Sol. + 1.6 G/L Sodium Dichromate + 2.082 G/L S.S.C.
B4B	.1461	.0872	.0743	.3076	B4BX	.8140	
B5T	.0536	.0296	.0384	.1216	B5TX	.1658	Salt Sol. + 0.8 G/L Sodium Dichromate + 1.199 G/L S.S.C.
B5B	.1305	.1215	.1101	.3621	B5BX	1.3952	
B6T	.1073	.0527	.0611	.2211	B6TX	.4479	Salt Sol. + 0.4 G/L Sodium Dichromate + 0.5485 G/L S.S.C.
B6B	.2809	.2811	.2512	.8132	B6BX	2.5873	
B7T	.2940	.2030	.1402	.6372	B7TX	.6998	Salt Sol. + 1.0 G/L S.S.C.
B7B	.2583	.4582	.3522	1.0687	B7BX	2.6123	
B8T	.0317	.0170	.0515	.1002	B8TX	.3909	Salt Sol. + 3.0 G/L S.S.C. + 2.3980 G/L Soda Ash
B8B	.1520	.2131	.1712	.5363	B8BX	1.7712	
B9T	.0313	.0194	.0875	.1382	B9TX	.1243	Salt Sol. + 3.2 G/L Sodium Dichromate + 0.3305 G/L Soda Ash
B9B	.0793	.0280	.0457	.1530	B9BX	.1856	
B10T	.1663	.0886	.1602	.4151	B10TX	.7766	Salt Sol. + 0.4 G/L Sodium Dichromate
B10B	.2953	.6257	.4355	1.3545	B10BX	2.3349	
B11T	.3229	.4433	.4364	1.2026	B11TX	1.2230	Salt Sol. + .04 G/L Mercoptobenzothiozole
B11B	.5256	.7297	.5150	1.7703	B11BX	2.6972	
B12T	.2589	.4036	.3781	1.0406	B12TX	.8464	Salt Sol. + 1.0 G/L Quebracho
B12B	.5441	.4236	.4390	1.4067	B12BX	2.8347	
B13T	.2600	.2208	.2383	.7191	B13TX	1.0832	Salt Sol. + 1.0 G/L Chrome Glucosate
B13B	.4778	.5609	.3303	1.3690	B13BX	2.3678	
B14T	.2809	.3469	.3312	.9590	B14TX	.3563	Salt Sol. + 1.0 G/L Cutch.
B14B	.6269	.7061	.5174	1.8540	B14BX	6.6019	
B15T	.2111	.2316	.2582	.7009	B15TX	1.0827	Salt Sol. + 1.0 G/L Chestnut Extract
B15B	.4189	.5385	.5980	1.5554	B15BX	2.6178	
B17T					B17TX	.1370	Salt Sol. + 3.75 G/L Nalco "A"
B17B					B17BX	.8259	
B18T					B18TX	.1081	Salt Sol. + 5.00 G/L Nalco "B"
B18B					B18BX	.5082	
B19T					B19TX	.1533	Salt Sol. + 5.00 G/L Nalco "C"
B19B					B19BX	.7851	
B20T					B20TX	.1667	Salt Sol. + 5.26 G/L Nalco "D"
B20B					B20BX	.6186	
B21T					B21TX	1.1245	Salt Sol. + 2 CC/L Nalco "E"
B21B					B21BX	2.2183	

D & RGW LABORATORY
20 PERCENT SALT SOLUTION CORROSION TEST

Weight Loss in Grams							Corroding Solution And Inhibitors
Spec. No.	1st. 30 day test	2nd. 30 day test	3rd. 30 day test	Total	Spec. No.	90 day test	
1T	.1523	.1093	.1107	.3723	1TX	.3054	Distilled Water
1B	.1746	.1582	.1316	.4644	1BX	.5219	
D2T	.2058	.2533	.2827	.7418	D2TX	1.3611	Salt Solution
D2B	.3961	.3504	.4177	1.6142	D2BX	2.0849	
D3T	.0448	.0318	.0241	.1007	D3TX	.1141	Salt Sol. + 3.2 G/L Sodium Dichromate + 3.037 G/L S.S.C.
D3B	.0791	.0400	.0534	.1725	D3BX	.2025	
D4T	.0820	.0384	.0266	.1470	D4TX	.2150	Salt Sol. + 1.6 G/L Sodium Dichromate + 1.801 G/L S.S.C.
D4B	.1576	.0614	.0714	.2904	D4BX	.2645	
D5T	.0857	.0434	.0229	.1520	D5TX	.2402	Salt Sol. + 0.8 G/L Sodium Dichromate + 1.067 G/L S.S.C.
D5B	.1681	.2096	.1565	.5342	D5BX	1.8226	
D6T	.1779	.0376	.0486	.2641	D6TX	.8600	Salt Sol. + 0.4 G/L Sodium Dichromate + 0.5925 G/L S.S.C.
D6B	.3728	.3256	.4369	1.1353	D6BX	2.2589	
D7T	.2118	.1526	.0685	.4329	D7TX	1.1253	Salt Sol. + 1.0 G/L S.S.C.
D7B	.3174	.3216	.3465	.9855	D7BX	2.1257	
D8T	.1660	.0883	.0341	.2884	D8TX	.6472	Salt Sol. + 3.0 G/L S.S.C. + 2.4165 G/L Soda Ash.
D8B	.2286	.1825	.1209	.5320	D8BX	1.3961	
D9T	.0330	.0220	.0301	.0851	D9TX	.0464	Salt Sol. + 3.2 G/L Sodium Dichromate + 0.3525 G/L Soda Ash
D9B	.0612	.0251	.0363	.1226	D9BX	.0856	
D10T	.1285	.1517	.1340	.4142	D10TX	.5281	Salt Sol. + 0.4 G/L Sodium Dichromate
D10B	.2572	.2132	.4197	.8901	D10BX	2.0229	
D11T	.2590	.2851	.3645	.9086	D11TX	1.2876	Salt Sol. + .04 G/L Mercoptobenzothiozole
D11B	.4173	.4311	.6984	1.5468	D11BX	2.3807	
D12T	.1520	.1823	.2548	.5891	D12TX	.8529	Salt Sol. + 1.0 G/L Quebracho
D12B	.3469	.4776	.6255	1.4500	D12BX	2.3093	
D13T	.2155	.1854	.2037	.6046	D13TX	2.0101	Salt Sol. + 1.0 G/L Chrome Glucosate
D13B	.3665	.4387	.4686	1.2738	D13BX	2.2374	
D14T	.2598	.1703	.1842	.6143	D14TX	1.0706	Salt Sol. + 1.0 G/L Cutch
D14B	.4069	.6036	.5094	1.5199	D14BX	1.4660	
D15T	.1535	.2115	.2480	.6130	D15TX	1.1086	Salt Sol. + 1.0 G/L Chestnut Extract
D15B	.3232	.3877	.4735	1.1844	D15BX	1.1957	
D17T					D17TX	.2506	Salt Sol. + 3.75 G/L Nalco "A"
D17B					D17BX	.6450	
D18T					D18TX	.2192	Salt Sol. + 5.00 G/L Nalco "B"
D18B					D18BX	.7175	
D19T					D19TX	.1136	Salt Sol. + 5.00 G/L Nalco "C"
D19B					D19BX	.6710	
D20T					D20TX	.1829	Salt Sol. + 5.26 G/L Nalco "D"
D20B					D20BX	.4418	
D21T					D21TX	1.0380	Salt Sol. + 2· CC /L Nalco "E"
D21B					D21BX	2.0525	

C & O LABORATORY
5 PERCENT SALT SOLUTION CORROSION TEST

Weight Loss in Grams							Corroding Solution And Inhibitors
Spec. No.	1st.30 day test	2nd.30 day test	3rd.30 day test	Total	Spec. No.	90 day test	
1T	0.3182	0.7826	0.4743	1.5751	1TX	0.5067	Distilled Water
1B	0.1548	0.2805	0.2810	0.7163	1BX	0.0775	" "
A2T	1.1243	1.7555	1.4032	4.2830	A2TX	3.9278	Salt Solution
A2B	0.8221	1.1287	0.7204	2.6712	A2BX	2.5663	" "
A3T	0.2180	0.3334	0.3858	0.9372	A3TX	0.4260	Salt Sol. + 3.2 G/L Sodium
A3B	0.2953	0.5299	0.3027	1.1279	A3BX	0.5490	dichromate + S.S.C.
A4T	0.3194	0.7819	0.2351	1.3364	A4TX	1.0791	Salt Sol. + 1.6 G/L Sodium
A4B	0.2821	0.7042	0.2776	1.2639	A4BX	1.0800	dichromate + S.S.C.
A5T	0.8837	1.5301	0.7422	3.1560	A5TX	3.4630	Salt Sol. + 0.8 G/L Sodium
A5B	0.4770	0.8432	0.5285	1.8487	A5BX	2.0579	dichromate + S.S.C.
A6T	0.9257	1.7114	1.0672	3.7043	A6TX	4.1209	Salt Sol. + 0.4 G/L Sodium
A6B	0.4784	0.8235	0.6346	1.9365	A6BX	2.0083	dichromate + S.S.C.
A7T	1.0034	1.7252	1.1752	3.9038	A7TX	3.8167	Salt Sol. + 1.0 G/L S.S.C.
A7B	0.6711	0.9319	0.8192	2.4222	A7BX	1.9929	
A8T	0.7176	0.9044	0.5881	2.2101	A8TX	2.6037	Salt Sol. + 3.0 G/L S.S.C.
A8B	0.5019	0.9102	0.5562	1.9683	A8BX	1.7589	
A9T	0.1885	0.5203	0.2208	0.9296	A9TX	0.2379	Salt Sol. + 3.2 G/L Sodium
A9B	0.2223	0.2595	0.2785	0.7603	A9BX	0.7975	dichromate + Soda Ash.
A10T	1.0511	1.4907	1.3031	3.8449	A10TX	4.4436	Salt Sol. + 0.4 G/L Sodium
A10B	0.5690	0.8140	0.7454	2.1284	A10BX	2.9539	dichromate + Soda Ash
A11T	1.3935	1.6505	1.4176	4.4616	A11TX	4.2459	Salt Sol. + .04 G/L
A11B	0.6486	0.9361	1.2857	2.8704	A11BX	2.7681	Mercoptobenzothiozole
A12T	1.2857	1.9892	1.5155	4.7904	A12TX	4.6169	Salt Sol. + 1.0 G/L
A12B	0.8617	1.1283	1.0310	3.0220	A12BX	2.2602	Quebracho
A13T	1.0946	1.5155	1.3832	3.9893	A13TX	4.0777	Salt Sol. + 2.0 G/L
A13B	0.7758	0.8534	0.7087	2.3379	A13BX	2.5443	chrome Glucosate
A14T	1.3095	1.6671	1.3131	4.2897	A14TX	4.3103	Salt Sol. + 1.0 G/L cutch.
A14B	0.8513	1.0891	0.9994	2.9398	A14BX	2.6056	
A15T	1.0122	1.2279	1.2108	3.4509	A15TX	4.4775	Salt Sol. + 1.0 G/L
A15B	0.9081	1.1364	0.8551	2.8996	A15BX	2.5978	chestnut extract
A16T	0.2584	0.5380	0.3908	1.1872	A16TX	1.0229	Salt Sol. + Sat.
A16B	0.2161	0.4218	0.2802	0.9181	A16BX	0.7524	concentration of Strontium chromate
A17T	1.2705	0.6990	-	1.9695*	A17TX	2.2159*	Salt Sol. + Nalco "A"
A17B	1.0598	1.0242	-	2.0840*	A17BX	1.8482*	
A18T	1.1229	0.5169	-	1.6398*	A18TX	2.4971*	Salt Sol. + Nalco "B"
A18B	0.8812	0.4982	-	1.3794*	A18BX	1.9080*	
A19T	1.3052	0.6746	-	1.9798*	A19TX	2.1611*	Salt Sol. + Nalco "C"
A19B	0.8531	0.5314	-	1.3845*	A19BX	2.4817*	
A20T	0.9265	0.5354	-	1.4619*	A20TX	1.3297*	Salt Sol. + Nalco "D"
A20B	0.9423	0.2538	-	1.1961*	A20BX	1.9514*	
A21T	1.4957	1.2425	-	2.7382*	A21TX	3.0358*	Salt Sol. + Nalco "E"
A21B	1.1332	1.1037	-	2.2369*	A21BX	3.3262*	

* 60 Day Test.

C & O LABORATORY
10 PERCENT SALT SOLUTION CORROSION TEST

Weight Loss in Grams							
Spec. No.	1st. 30 day test	2nd. 30 day test	3rd. 30 day test	Total	Spec. No.	90 day test	Corroding Solution And Inhibitors
1T	0.3182	0.7826	0.4743	1.5751	1TX	0.5067	Distilled Water
1B	0.1548	0.2805	0.2810	0.7163	1BX	0.0775	" "
B2T	1.2096	1.4002	0.3202	2.9300	B2TX	4.0372	Salt Solution
B2B	0.8569	1.0983	0.2356	2.1908	B2BX	2.7810	" "
B3T	0.2244	0.4230	0.3564	1.0038	B3TX	0.4881	Salt Sol. + 3.2 G/L Sodium
B3B	0.2051	0.3410	0.4088	0.9549	B3BX	0.6231	dichromate + S.S.C.
B4T	0.1462	1.0358	1.4107	2.5927	B4TX	1.4394	Salt Sol. + 1.6 G/L Sodium
B4B	0.3129	0.2374	0.8109	1.3612	B4BX	1.1827	dichromate + S.S.C.
B5T	0.3792	1.0972	0.8387	2.3151	B5TX	2.8139	Salt Sol. + 0.8 G/L Sodium
B5B	0.4487	0.4891	0.3767	1.3145	B5BX	2.1595	dichromate + S.S.C.
B6T	0.9235	1.1662	0.8555	2.9452	B6TX	3.2815	Salt Sol. + 0.4 G/L Sodium
B6B	0.5990	0.8186	0.8290	2.2466	B6BX	2.3436	dichromate + S.S.C.
B7T	0.8449	1.2692	1.1895	3.3036	B7TX	3.5721	Salt Sol. + 1.0 G/L S.S.C.
B7B	0.7287	0.7650	0.6078	2.1015	B7BX	2.6295	
B8T	0.3843	0.8972	0.5791	1.8606	B8TX	2.3533	Salt Sol. + 3.0 G/L S.S.C.
B8B	0.4947	0.7739	0.6409	1.9095	B8BX	2.1040	
B9T	0.2113	0.0900	0.5932	0.8945	B9TX	0.4041	Salt Sol. + 3.2 G/L Sodium
B9B	0.2337	0.1613	0.4025	0.7975	B9BX	0.3849	dichromate + soda ash.
B10T	0.8401	1.2940	0.9783	3.1124	B10TX	3.4538	Salt Sol. + 0.4 G/L Sodium
B10B	0.6749	0.7218	0.5145	1.9112	B10BX	1.7403	dichromate + soda ash.
B11T	1.1017	1.4990	1.2848	3.8855	B11TX	4.3332	Salt Sol. + .04 G/L
B11B	0.9075	0.9914	0.5887	2.4876	B11BX	1.9708	Mercoptobenzothiozole
B12T	1.0073	1.3775	1.1901	3.5749	B12TX	4.4529	Salt Sol. + 1.0 G/L
B12B	0.9359	1.0445	0.7952	2.7756	B12BX	2.6033	Quebracho
B13T	0.9292	1.1745	1.1183	3.2220	B13TX	4.0802	Salt Sol. + 2.0 G/L
B13B	0.8220	0.7394	0.5418	2.1032	B13BX	2.6906	chromeglucosate
B14T	0.8907	1.2358	1.1223	3.2488	B14TX	4.3647	Salt Sol. + 1.0 G/L cutch.
B14B	0.8991	1.0477	0.8752	2.8220	B14BX	2.4401	
B15T	0.9338	1.0254	0.8684	2.8276	B15TX	4.3001	Salt Sol. + 1.0 G/L
B15B	0.6821	0.9110	0.5689	2.1620	B15BX	2.4437	chesnut extract
B16T	0.2411	0.5688	0.6119	1.4218	B16TX	1.9621	Salt Sol. + saturated
B16B	0.2720	0.4825	0.2474	1.0019	B16BX	1.3638	concentration of Strontium chromate
B17T	1.1398	0.7062	-	1.8460*	B17TX	2.1442*	Salt Sol. + Nalco "A"
B17B	0.9638	0.3537	-	1.3175*	B17BX	2.0800*	
B18T	1.2786	0.6228	-	1.9014*	B18TX	1.8054*	Salt Sol. + Nalco "B"
B18B	0.8225	0.4976	-	1.3201*	B18BX	1.6955*	
B19T	1.0315	0.6226	-	1.6541*	B19TX	1.5747*	Salt Sol. + Nalco "C"
B19B	0.9392	0.4661	-	1.4053*	B19BX	1.6384*	
B20T	0.7121	0.6021	-	1.3142*	B20TX	1.2093*	Salt Sol. + Nalco "D"
B20B	0.5043	0.5646	-	1.0689*	B20BX	1.2647*	
B21T	1.0985	1.2693	-	2.3678*	B21TX	3.2358*	Salt Sol. + Nalco "E"
B21B	0.9239	1.0526	-	1.9765*	B21BX	2.0201*	

* 60 Day Test.

A daily log should be kept of the tests, showing temperature, and any other matter that might be of interest.

Results of the Tests

The tests were carried out by the laboratories in accordance with the foregoing procedure, except that the A. T. & S. F. laboratory was unable to carry out the tests with the 15-percent salt solution due to unexpected developments. Salt was furnished the other laboratories by the D. & R. G. W. laboratory. The chemical analysis of the salt was as follows:

Calcium chloride—0.42 percent
Magnesium chloride—Trace
Sodium chloride—Remainder

Some additional inhibitors were included in the tests other than given in the foregoing procedure.

The results of the tests at the respective laboratories are shown in the tables.

Conclusions from the Laboratory Tests

The results from the laboratory tests consistently indicate the best performance may be expected from the use of sodium dichromate and soda ash as an inhibitor. The tests also show that this inhibitor effectively inhibited the corrosion due to the brine and that generally the corrosion from the brine containing this inhibitor was even less than from distilled water alone. The sodium dichromate and sodium silicate compound (S.S.C.) also gave good protection, but the cost of this inhibitor would be appreciably greater.

The results of the laboratory tests are very encouraging. However, it must be noted that these are laboratory results only. Further work must be undertaken next year to determine the most practical means of applying the inhibitor to obtain the desired concentration in the brine drippings from refrigerator cars. Field tests are also contemplated to determine whether those inhibitors showing best laboratory protection will give equally good protection in actual service conditions. This work must be completed before definite recommendations for use of the inhibitor may be made.

Acknowledgment

The foregoing tests were made possible through the courtesy and with the assistance of Mr. K. F. Nystrom, mechanical assistant to chief operating officer, Mr. H. G. Miller, engineer of tests, and Mr. L. E. Grant, metallurgical and welding engineer of the Chicago, Milwaukee, St. Paul and Pacific Railroad; Mr. C. J. Geyer, engineer maintenance of way, Mr. C. M. Angel, engineer of tests, and Mr. A. S. Perry, chief chemist of the Chesapeake and Ohio Railway; Mr. A. E. Perlman, engineer maintenance of way, Mr. Ray McBrian, engineer of tests, and Mr. Walter Leaf, research technician, of the Denver and Rio Grande Western Railway. Acknowledgment and appreciation is extended Dr. F. N. Speller, advisory engineer, Department of Metallurgy and Research, National Tube Company, for his suggestion of inhibitors and details of the testing procedure.

This report is offered as information with recommendation that the subject be continued.

Appendix K

(12) Specifications for Laying Rails Designed to Set Up the Requirements for Good Workmanship

I. H. Schram (chairman, subcommittee), Lem Adams, A. L. Bartlett, W. H. Bettis, W. H. B. Bevan, F. J. Bishop, L. H. Bond, A. Chinn, H. R. Clarke, L. W. Deslauriers, H. F. Fifield, O. H. Frick, C. J. Geyer, H. H. Harman, N. M. Hench, F. W. Hillman, E. T. Howson, C. T. Jackson, F. J. Jerome, A. A. Johnson, J. H. Kelly, E. E. Martin, F. H. Masters, J. A. Reed, F. S. Schwinn, J. F. Shaffer, G. L. Sitton, G. M. Strachan, J. G. Wishart.

Specifications for Laying Rails

The location shall be as designated by chief maintenance officer of the railroad.

The several classes of rail shall be laid as follows:

Class of Rail	*Std. Length Feet*	*Color or Design*	*Use*
1st quality—low carbon:	39	Uncolored	Any track—preferably tangent.
1st quality—high carbon:	39	Blue end	Any track—preferably curves.
1st quality—"A" Rails:		Yellow end	Tangent track—not to be used where inspection is difficult.
1st quality—short lengths:		Green end	Any track (see second paragraph under unloading)
2nd quality—	39 or under	White end	Any tangent track or curves not to exceed 3°, preferably in tracks used largely for freight or where speed does not exceed 50 mph. Not to be used where inspection is difficult.
X Rails:	39 or under	Brown end	Freight tracks, turnout side of side tracks or where designated by chief maintenance officer.

UNLOADING

Rail shall be unloaded from the car with an approved derrick or crane and placed with the head up without dropping, with sufficient support under the base and with the brand facing toward the center of the track.

Rails shall be unloaded opposite the locations in which they are to be placed in the track, with suitable gaps being allowed for short lengths. Rails shall be so placed that the joints in each line of rail shall be not more than 30 inches from the centers of the opposite rails and preferably not more than 18 inches. Locations of joints can be best determined with a steel tape.

Proper lengths of rail for road crossings, station platforms, bridges and other special locations shall be unloaded in a safe and convenient location, where they will not constitute an obstruction.

To minimize the cutting of new full-length rails, short rails shall also be distributed in proper places to provide for proper spacing at insulated joints and for connections to switches.

No rail less than 25 feet long shall be used in main tracks with the exception that shorter rails not less than 14 feet long may be used for temporary closures and for connections within turnouts.

Rail shall be so distributed that joints will not be placed in road crossings, within the limits of switch points or guard rails, or within 6 feet of the ends of open-floor bridges. Rails at least 60 feet long should be provided for such locations.

Joints, turnouts and fastenings shall be unloaded and distributed concurrently with the rail, except that small material shall be left in the containers until the rail is laid.

PREPARATION OF TRACK

Track shall be in good surface prior to the laying of new rail, and where curve realinement work will require heavy throws, such work shall be done before the new rail is laid.

No portion of the track structure, the absence of which will impair its integrity, may be removed prior to the relaying of the rail. Full flag protection or slow-order protection, as may be necessary, shall be provided in cases where rail is being laid under traffic.

LAYING

All rail ends and angle bars shall, in advance of laying, be painted on the contact surfaces with a lubricant equal to black lubricating oil.

Wherever necessary ties shall be so adzed that the tie plates shall have a full and uniform bearing on them and so that the tie plate beds on each tie shall be in the same plane. All spike holes shall be plugged with treated tie plugs after the old spikes and tie plates have been removed. Creosote oil, heated when necessary, shall be applied to the ties after adzing.

Where new rail is to be laid, the track shall be fully tie plated, if possible, after preparation of tie plate beds and before the placing of the new rail.

Where practical, rail shall be laid against the current of traffic on double-track lines and against the predominant tonnage movement on single track.

Standard expansion shims shall be placed between the ends of adjacent rails to insure the proper space allowance for expansion as indicated in the following table:

Temperature of rail, degrees F.	*160 Joints per Mile 33-Foot Rails*	*135 Joints per Mile 39-Foot Rails*
0 to 25	3/16 inch	1/4 inch
26 to 50	1/8 inch	3/16 inch
51 to 75	1/8 inch	1/8 inch
76 to 100	1/16 inch	1/16 inch
Over 100	None	None

Where metal shims are used they shall be removed to within 12 rails of the laying. Wooden or fiber shims need not be removed.

In tunnels where the temperature is above 70 degrees F., rails shall be laid close without bumping; where the temperature is below 70 degrees F., an opening of 1/16 inch shall be allowed (for 39-foot rail) for each 20 degrees F. reduction in temperature.

A rail thermometer shall be used to ascertain the temperature of the rail and in making the reading it shall be placed on the rail base on the side away from the sun.

Rails shall be placed one at a time except that in cases of busy traffic where trains cannot be diverted to other tracks, stretches of rail not over 20 in number may be bolted together at one side of the track and then lined into place, using care to maintain the expansion allowance uniformly. Rails shall be laid without bumping or striking and with the ends square.

Rail joints shall be applied before the track is spiked, the joint bars to be lined up with rail in vertical position and the bolts tightened by starting in the middle of the joint and working towards the outer ends. Spring washers or other similar approved appliances shall be used.

Spikes shall be driven vertically with the face of the shank in contact with the base of the rail, and shall be so driven that it will not be necessary to straighten them during driving. Spikes shall be so staggered that all the outside spikes shall be on the same sides of the ties and all the inside spikes on the opposite sides.

Rail anchors shall be applied prior to the passage of a train over the new rail.

In laying the second line of rail, gaging shall be done at least at every third tie.

When necessary to make a temporary connection for the passage of a train, the union shall be made with a rail of the section being renewed. The closure rail shall not be less than 14 feet long, and shall be connected to the new rail by a compromise joint if the rails are of different sections. The connection rail shall have a full number of bolts and spikes. At the completion of a day's work a short section of new rail not less than 18 feet long shall be used in making the closure and shall be connected to the old rail with a compromise joint.

COMPLETION OF WORK

All rail laid down on any given day shall be fully spiked and bolted at the close of the day's work. Bolt holes made in the field shall be drilled and not burned with a torch.

After rail has been laid the tops of adjacent rail ends shall be ground to a level surface.

Markings indicating the classification of released rail shall be placed on it promptly, and such rail and its fixtures loaded promptly.

It is desirable that other renewals of track material shall follow rail laying as promptly as possible.

All ties on which the new rail does not have a full bearing shall be tamped and the spikes re-driven; proper slow orders shall be maintained until this is done. If weather conditions do not permit this work to be carried out, any loose ties may be temporarily shimmed.

Where necessary, bolts shall be given a second tightening. After the ballasting and resurfacing of the track have been completed the bolts shall be tested and, if required, brought to a pre-determined tension.

The committee submits this report as information and for consideration for the Manual in 1941.

Appendix L

(14) Spirals for High Speed Operation

Collaborating with Committee 16—Economics of Railway Location and Operation

C. W. Baldridge (chairman, subcommittee), A. L. Bartlett, L. H. Bond, R. W. E. Bowler, A. Chinn, H. R. Clarke, L. W. Deslauriers, H. F. Fifield, C. J. Geyer, H. H. Harman, F. W. Hillman, E. T. Howson, T. T. Irving, C. T. Jackson, J. H. Kelly, K. R. McLennan, J. B. Myers, G. L. Sitton, J. G. Wishart.

Collaborating Members from Committee 16: S. E. Armstrong, J. C. Bradley, Olive W. Dennis, E. K. Eugene, R. P. Forsberg, E. A. Humphreys, L. G. Morphy, E. H. Roth, F. A. Russell, O. E. Selby, H. M. Shepard, H. M. Stout.

Early in the existence of this Association, the subject of spirals for curves was assigned for committee work and was studied and reported upon from time to time. In the Convention of 1911 the matter which, with slight changes, is still in the Manual (pages 5–23 to 5–31, inclusive), was presented and adopted.

Because of the great increase in speeds for all kinds of trains that has taken place, the subject has attained greater importance, with the result that it has again been assigned for study and revision. A comparison of the matter which is now in the Manual with several other treatises on the subject of spiral curves, has shown that some factors now given in the Manual are not clearly defined or determined.

It seems proper that a list of the terms to be used and the abbreviations for them as now given in the Manual, should be followed by a statement of the known or measurable factors and those followed by formulas for the determination of the unknown factors.

The figure in the Manual to which reference is made for explanation of the terms and formulas is retained after making a slight revision for the purpose of eliminating conflicting meanings given to certain terms, as follows:

Capital letter V which is now defined as the distance on the tangent through *S.C.* from point *S.C.* to its intersection with the primary tangent through *T.S.*, which distance is the shorter spiral tangent, is changed to Q to avoid conflicting with V used to indicate Velocity.

Small letter v is also changed to small q for a like reason and for consistency.

Pages 5–23—Changes in definitions or letters representing various notations are as follows:

1. After D in the list of notations insert E = Elevation of the outer rail on curves.

2. Following I insert small i and define i = the initial deflection angle, which is the deflection for spiral chord No. 1.

3. Small k, change the definition to read k = the amount of the central angle of the spiral subtended by the first chord thereof.

4. After L insert capital N and show N = the length of the spiral in chords between *T.S.* and *S.C.*

5. Insert small n and show n = length of spiral in chords from the *T.S.* to any given point on the spiral.

Page 5–24—

6. Change definition of capital S to read S = train speed in miles per hour.

7. Change small s to read s = train speed in feet per second.

CALCULATION AND STAKING OF SPIRALS

The notations and formulas herein apply to a ten-chord spiral based upon an increase in curvature proportional to the square of the lengths, measured in chords.

NOTATIONS

(a) In designations for curve points, the first initial represents the alinement on the side toward station zero, the second that away from station zero.

(b) Where the word "station" is used, a length of 100 feet is meant.

T.C. The point of change in alinement from tangent to circular curve.

C.T. The point of change from circular curve to tangent.

C.C. The point of change in degree of circular curve; the point of compound curve.

P.R. The point of reverse curve.

T.S. The point of change from tangent to spiral.

S.C. The point of change from spiral to circular curve.

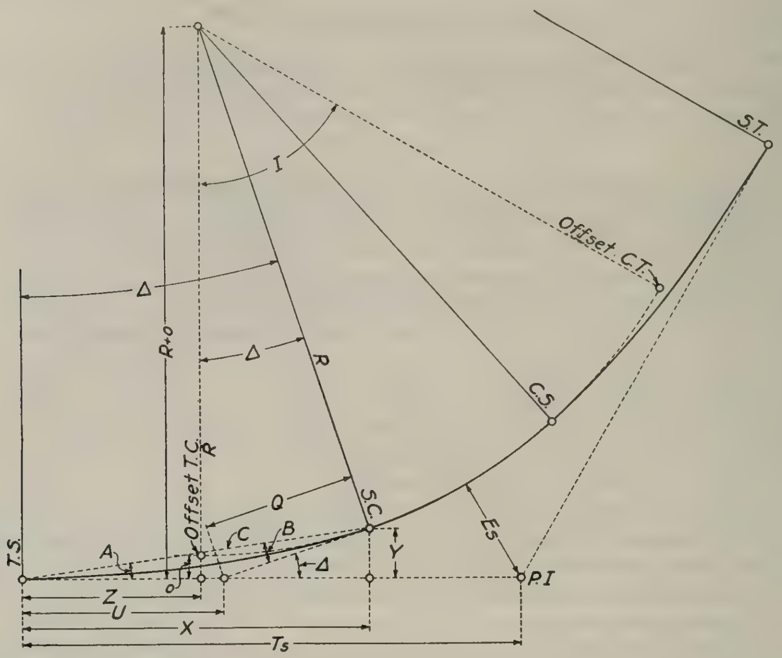
C.S. The point of change from circular curve to spiral.

S.T. The point of change from spiral to tangent.

S.S. The point of change from one spiral to another.

The symbols *T.C.* and *C.T.*, *T.S.* and *S.T.*, and *S.C.* and *C.S.* become transposed when the direction of stationing is changed.

a	The angle between the tangent at the *T.S.* and the chord from the *T.S.* to any point on the spiral.
A	The angle between the tangent at the *T.S.* and the chord from the *T.S.* to the *S.C.*
b	The angle at any point on the spiral, between the tangent at that point and the chord from the *T.S.*
B	The angle at the *S.C.* between the chord from the *T.S.* and the tangent at the *S.C.*
c	The chord from the *T.S.* to any point on the spiral.
C	The chord from the *T.S.* to the *S.C.*
d	The degree of curve at any point on the spiral.
D	The degree of central circular curve.
E	Elevation of the outer rail on curve.
f	The angle between any chord of the spiral (produced if necessary) and the tangent through the *T.S.*
I	The angle between the initial and final tangents; the total central angle of circular curve and spirals.
i	The initial deflection which is the deflection for chord No. 1.
k	The central angle of the spiral subtended by the first chord thereof.
l	The length of the spiral in feet from the *T.S.* to any given point.
L	The length of the spiral in feet from the *T.S.* to the *S.C.*
N	The length of the spiral in chords between the *T.S.* and *S.C.*
n	The length of the spiral in chords from the *T.S.* to any given point therein.
o	The ordinate of the offset *T.C.*; the distance between the tangent and a parallel tangent to the offset curve.
r	The radius of the osculating circle at any given point of the spiral.
R	The radius of the central circular curve.
S	Train speed in miles per hour.
s	Train speed in feet per second.
U	The distance on the tangent from the *T.S.* to the intersection with a tangent through the *S.C.*; the longer spiral tangent.



u	The distance on the tangent from the *T.S.* to the intersection with a tangent through any given point of the spiral.
q	The distance on the tangent, through any given point, from that point to the intersection with the tangent through *T.S.*
Q	The distance on the tangent through the *S.C.* from the *S.C.* to the intersection with the tangent through the *T.S.*; the shorter spiral tangent.
x	The abscissa or tangent distance of any given point, referred to the *T.S.*
X	The abscissa or tangent distance of the *S.C.*, referred to the *T.S.*
y	The ordinate or tangent offset of any point on the spiral.
Y	The ordinate or tangent offset of the *S.C.*
Z	The abscissa or tangent distance of the offset, *T.C.* referred to the *T.S.*
δ	The central angle of the spiral from the *T.S.* to any given point.
Δ	The central angle of the whole spiral.
Ts	The tangent distance of the spiraled curve; distance from *T.S.* to *P.I.* (point of intersection of tangents).
Es	The external distance of the offset curve.

KNOWN QUANTITIES AND FACTORS

I	In all curves the factor I is known or measurable—being the angle between the original tangents.
D	In existing tracks the factor D is known or measurable—being the degree of the circular curve, and in the construction of new track D is assumed or measured.
L	The length of spiral is subject to calculation by Formula (2) but since **Formula (2)** is based upon the assumed rise in elevation of the outer rail of 1¼ inches per second of train travel, the only value of calculating the length of spiral is to

keep spirals uniform in length proportional to the degree of curve. The calculated length of spiral thus determined should be regarded as the minimum length.

Having the length of spiral determined or assumed the value of delta is easily found by multiplying the degree of the circular curve by one half of the length of the spiral, in stations. The remaining factors may be calculated by the formulas given as follows:

FORMULAS FOR THE EXACT DETERMINATION OF THE FUNCTIONS OF THE TEN-CHORD SPIRAL WHEN THE CENTRAL ANGLE DOES NOT EXCEED 45 DEGREES

$$\left.\begin{aligned} d &= kn \\ k &= \frac{\Delta}{N^2} \end{aligned}\right\} \tag{1}$$

$$\left.\begin{aligned} \delta &= \frac{kn^2}{2} = \frac{dn}{2} = \frac{kl^2}{20{,}000} = \frac{dl}{200} \\ \Delta &= \frac{kN^2}{2} = \frac{DN}{2} = \frac{kL^2}{20{,}000} = \frac{DL}{200} \end{aligned}\right\} \tag{2}$$

$$A = \tfrac{1}{3}\,\Delta - 0.00297\,\Delta^3 \text{ seconds} \tag{3}$$

$$B = \Delta - A \tag{4}$$

$$C = L\,(\cos 0.3\,\Delta + 0.004 \operatorname{exsec} \tfrac{3}{4}\,\Delta) \tag{5}$$

$$X = C \cos A \tag{6}$$

$$Y = C \sin A \tag{7}$$

$$U = \frac{C \sin B}{\sin \Delta} \tag{8}$$

$$Q = \frac{C \sin A}{\sin \Delta} \tag{9}$$

$$R = \frac{50}{\sin \frac{1}{2} D} \tag{10}$$

$$Z = X - R \sin \Delta \tag{11}$$

$$o = Y - R \operatorname{vers} \Delta \tag{12}$$

$$Ts = (R + o) \tan (1/21) + Z \tag{13}$$

$$Es = (R + o) \operatorname{exsec} (1/21) + o \tag{14}$$

The above formulas are for precise calculations where for any reason exact determinations of fractional chord points are needed.

FORMULAS FOR FIELD USE

The formulas presented above are best adapted for the preparation of tables. For use in the field, the following empirical formulas are sufficiently accurate and have the advantage that they do not require the computation of the long chord. The formulas can all be applied for the functions of any parts of the spiral without serious error, though they are derived for the completed spiral.

$$\left.\begin{aligned} a &= \tfrac{1}{3}\,\delta \\ A &= \tfrac{1}{3}\,\Delta \end{aligned}\right\} \tag{15}$$

$$i = \frac{A}{N^2} = \frac{A}{100} \tag{16}$$

Formulas (15) and (16) are sufficiently accurate for turning deflection when δ (or Δ) does not exceed 15 degrees.

A similar approximation may be used when the transit is set at an intermediate point on the spiral if the included central angle from the transit point to the point of sight. less the included angle from the *T.S.* to the transit point, does not exceed 15 degrees.

$$X = L - L\left(\tfrac{1}{3}\ vers\ \tfrac{3}{4}\Delta + 1/22\ vers\ \tfrac{1}{2}\Delta\right) \tag{17}$$

$$Y = \frac{L}{39}\left(20\ sin\ \tfrac{1}{2}\Delta + 3\ sin\ \Delta\right) \tag{18}$$

$$U = L\left(\tfrac{2}{3} + 10/39\ exsec\ \tfrac{1}{2}\Delta + 1/10\ vers\ \tfrac{1}{4}\Delta\right) \tag{19}$$

$$Q = L\left(\tfrac{1}{3} + 10/39\ exsec\ \tfrac{1}{2}\Delta\right) \tag{20}$$

$$o = \frac{L}{10}\left(sin\ \tfrac{1}{2}\Delta + sin\ \tfrac{1}{3}\Delta\right) cos\ \tfrac{1}{2}D \tag{21}$$

$$Z = L\left(0.5 - 0.12885\ vers\ \tfrac{1}{2}\Delta\right) - 0.073\ D\ sin\ \Delta \tag{22}$$

$$L = \frac{370.82}{cos\ 21/60\ D}\left(1 + 0.000018\ Do\right)\sqrt{\frac{o}{D}} \tag{23}$$

The errors in the application of the above empirical formulas are as tabulated below:

Errors—Millionths of *L*

	(17)	(18)	(19)	(20)
5°	None	None	None	None
10°	None	None	None	None
15°	None	None	None	None
20°	+1	None	None	None
25°	+2	None	None	None
30°	+3	None	+2	None
35°	+6	None	+4	None
40°	+9	—1	+6	—2
45°	+14	—3	+8	—5

STAKING SPIRALS BY DEFLECTIONS

Calculating the Curve

Having the degree of the circular curve known and the length of the spiral decided upon—

Since half of the length of the spiral lies before and half of it behind the original tangent point of the circular curve, the amount of central angle to be taken from the circular curve and spread over the length of the spiral equals the degree of the circular curve times half of the length of the spiral in stations.

With a 4-degree circular curve and a 500-foot length of spiral, $\Delta = 4$ degrees $\times\ 2\tfrac{1}{2}$ stations $= 10$ degrees.

A = the angle between the primary tangent and the long chord of the spiral equals $\tfrac{1}{3}\Delta$ (formulas 15) and i the initial deflection $\frac{A}{10^2}$, therefore $A = \tfrac{1}{3}\Delta = 3°20' = 200'$

$$i = 200' \div (10)^2 \text{ or } (100) = 2' \text{ (formula 16)}.$$

The deflections for each following chord is i times the chord number squared.

Staking the Curve

Set the transit on the *T.S.* point and set the stakes at each chord length using the angle of deflection calculated for that chord. If the central angle Δ of the spiral exceeds 15 degrees, formula (3) should be used for determining the value of A, or else an additional transit point should be used between the *T.S.* and *S.C.* If an additional transit point is to be used the transit, when set up over the new point, must be back-sighted on the *T.S.* and a tangent turned by setting off a deflection of twice the angle of deflection from *T.S.* to the point being used. The curve may then be continued.

Upon establishing the *S.C.* point the transit should be moved to that point and the tangent again established using twice the forward deflection from the back sight point. From this tangent the circular part of the curve may be "run in" in the customary manner. After the circular part of the curve has been run, the transit may be moved to the *C.S.* point and the "run off" spiral may be staked from that point by using double the deflections calculated for the first spiral but in reverse order.

Note:—If the beginner has any difficulty with these deflections, the transit should be set at the previous *S.C.* point and the deflections to the stakes already set can be read in reverse direction, thus giving a check on the operation required on the last leg of the spiral.

APPLYING THE SPIRAL TO COMPOUND CURVES

Locate the compound point in an established curve—

Calculating the Spiral

Determine what length of spiral is desired, then proceed just as if a like spiral, originating from tangent, were being calculated, except that the central angle of the spiral equals the difference between the degree of curvature on the two sides of the *C.C.* point times half the length of spiral.

Staking the Spiral

Beginning on the curve of lesser degree—

After locating the point where the spiral must begin, add the deflection for the first chord of the spiral to the deflection for the circular curve for the same length of chord, and set the stake. Continue by using the spiral angle for each chord added to the constant deflection of the circular curve of the lesser degree throughout the ten chords. The final deflection will have brought the curvature to the degree of the second part of the circular curve.

Recommendations

It is recommended that the matter now in the Manual from the heading "Spirals" on page 5–23 to the sub-heading "Staking Spirals by Offsets" on page 5–26 be deleted and that the matter in this report from the heading "Calculations and Staking of Spirals" to the end of the table headed "Errors—Millionths of L" be substituted therefor.

It is also recommended that the paragraph on page 5–26 of the Manual under the heading "Staking Spirals by Offsets" be retained and inserted following the table headed "Errors—Millionths of L".

It is further recommended that the matter now in the Manual on page 5–26 under the heading "Staking Spirals by Deflections" down to the third line from the bottom of the page be deleted and that the matter under the same heading in this report, to the ending of instructions for applying the spiral to compound curves, be inserted in place thereof, and that the matter beginning with the third line from the bottom of page 5–26 of the Manual to the bottom of page 5–31 be retained as it now is.

Report of Committee 4—Rail

John V. Neubert, *Chairman,*
J. B. Akers
John E. Armstrong,
W. J. Backes
W. C. Barnes
A. F. Blaess
L. H. Bond
N. J. Boughton
C. B. Bronson
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H. A. Cassil
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H. R. Clarke
E. J. Cullen
W. A. Duff
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F. M. Graham
G. W. Harris
B. Herman
F. S. Hewes
C. W. Johns*
Maro Johnson
W. H. Kirkbride
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Ray McBrian
Wm. Michel
C. E. Morgan
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Robert Faries, *Vice-Chairman,*
W. H. Penfield
Philip Petri
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R. T. Scholes
G. R. Smiley
A. N. Talbot
J. C. Wallace
Barton Wheelwright
J. E. Willoughby
W. P. Wiltsee
Louis Yager
Committee.

To the American Railway Engineering Association:

Your committee respectfully reports on the following subjects:

1. Revision of Manual (Appendix A).

2. (a) Further research, including details of mill practice and manufacture as they affect rail quality and rail failures, giving special attention to transverse fissure failures, and other defects in the head, web and base, collaborating with Rail Manufacturers' Technical Committee (Appendix B). Progress report.

(b) Specifications for thermal treatment of rail, such as controlled cooled, Brunorized, etc. (Appendix B). Progress report.

3. Compilation of Statistics.

(a) All rail failures, making special study of transverse fissure failures (Appendices C and D). Progress reports.

(b) Compilation of statistics for determining the performance of controlled cooled and Brunorized rail in service with respect to rail failures, with the view toward evaluating the higher price paid for treated than for untreated rails (Appendix E). Progress report.

4. Cause and prevention of rail battering and methods of reconditioning rail ends, fastenings, and frogs in track (Appendix F). Progress report.

5. Economic value of different sizes of rail (Appendix G). Progress report.

6. Continuous welding of rail, collaborating with Committee 5—Track and Special Committee on Stresses in Railroad Track (Appendix H). Progress report.

7. Service tests of various types of joint bars (Appendix I). Progress report.

8. Investigate joint bar failures and give consideration to the revision of design and specifications (Appendix J). Progress report.

The Committee on Rail,
John V. Neubert, *Chairman.*

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* Died September 16, 1939.

Bulletin 416, February, 1940.

Charles W. Johns

Charles W. Johns, chief engineer, Chesapeake & Ohio Railway, at Richmond, Va., a member of Committee 4—Rail, died on September 16, 1939.

Mr. Johns was born on December 28, 1875, at Farmville, Va. He entered railway service on September 1, 1899, as instrumentman on the Chesapeake & Ohio and later served as assistant engineer on construction. In August, 1903, he became assistant engineer in the maintenance department at Hinton, W. Va., and in December, 1904, was appointed assistant division engineer at that place. Mr. Johns became division engineer at Hinton in May, 1906, and two months later was appointed assistant engineer maintenance of way with the same headquarters. From May, 1910, until February, 1914, Mr. Johns served as engineer maintenance of way at Huntington, W. Va., and from the latter date until August, 1920, as engineer, branch lines, at Richmond, Va. In August, 1920, he was appointed engineer of construction, and was advanced to chief engineer in January, 1923.

Mr. Johns became a member of the American Railway Engineering Association early in 1907. He served on the Committee on Signs, Fences and Crossings (now the Committee on Highways) in 1909 and 1910, and from 1925 until the time of his death he served faithfully as a member of the Committee on Rail.

The committee wishes to record here its appreciation of his many estimable qualities, and the profound regret occasioned by his death.

THE COMMITTEE ON RAIL,
JOHN V. NEUBERT, *Chairman.*

Appendix A

(1) Revision of Manual

Robert Faries (chairman, subcommittee), John E. Armstrong, W. C. Barnes, A. F. Blaess, N. J. Boughton, C. B. Bronson, W. J. Burton, E. E. Chapman, W. A. Duff, J. M. Farrin, F. M. Graham, G. W. Harris, B. Herman, Maro Johnson, B. R. Kulp, John V. Neubert, E. E. Oviatt, W. H. Penfield, A. N. Reece, L. H. Scheifele, Louis Yager.

The committee recommends no revision of the Manual.

The committee, however, recommends that Paragraph 3 of Tentative Specifications for Controlled Cooling of Rails shown on page 644, Vol. 38, 1937 Proceedings, which were submitted as information, be revised as follows:

3. Any rails showing a temperature thus determined below 725 degrees F., shall not be charged.

This report is offered as information.

Appendix B

(2) (a) Further Research, Including Details of Mill Practice and Manufacture as They Affect Rail Quality and Rail Failures

Giving Special Attention to Transverse Fissure Failures and Other Defects in the Head, Web and Base, Collaborating With Rail Manufacturers' Technical Committee,

and

(b) Specifications For Thermal Treatment of Rail, (Such as Controlled Cooled, Brunorized, etc.)

John V. Neubert (chairman, subcommittee), John E. Armstrong, W. C. Barnes, L. H. Bond, C. B. Bronson, E. E. Chapman, Robert Faries, Philip Petri, W. P. Wiltsee, Louis Yager.

Rails Investigation

I. WORK DONE DURING 1939

1. Fifth Progress Report

Details of the work of the investigation from March, 1938, to March, 1939, are given in the Fifth Progress Report, presented before the AREA at the 1939 meeting, and published in the Proceedings for 1939 (Vol. 40, pages 655–686). The report herewith submitted gives a general summary of the work of the investigation from December, 1938, to December, 1939.

2. Temperature Limits for Controlled Cooling of Rails

Further study of the controlled cooling of rails has been made at the works of the Dominion Steel and Coal Corporation, Sydney, N. S., and at the Gary Works of the Carnegie–Illinois Steel Corporation. In these tests steel while still molten in the ingot mold was treated with hydrogen gas with the result that a large number of shatter cracks were found in hot-bed cooled rails. It was found that proper controlled cooling would prevent the formation of shatter cracks even under these abnormally severe conditions. At all the mills tests were made to see whether shatter cracks found in hot-bed cooled rails were also eliminated by controlled cooling. Only a few heats not treated with hydrogen yielded shatter-cracked rails even in the hot-bed cooled rails, and no shatter cracks were developed in rails controlled cooled within certain limits of temperature and time. These limits are discussed in detail in the Fifth Progress Report.

In the course of this study of temperature limits for controlled-cooled rails two further lines of study have been initiated: (1) A study of the prevention of shatter cracks by holding the rail at a given temperature (below 1100 deg. F., else the steel will be unduly softened). This has been found effective in preventing the formation of shatter cracks and is discussed in the Fifth Progress Report, Bulletin 411, June–July, 1939, and Vol. 40 of the Proceedings, 1939. (2) A study has been made in some steel mills of the actual variation in rate of cooling among the different rails of the pile in the cooling box. This study has shown that there may be a rather wide variation in rates of cooling, so that if the middle rail of the pile cools slowly enough to inhibit shatter cracking, the fastest cooling rails (usually at the bottom corners of the pile) may cool too rapidly, and shatter cracking might occur.

3. Work Toward Revision of the Present Tentative Recommended Practice for Controlled Cooling of Rails

Some preliminary work has been done on this subject, and preliminary discussions have been held with the Advisory committee. Further study of the actual rates of cooling in mill containers of various types seems necessary before the present rather rigid requirements for temperatures and times can safely be modified. In this connection efforts are being made to study each reported failure of a controlled-cooled rail. So far (November 22, 1939) there has been no case of a failure due to a transverse fissure in service of a rail controlled cooled according to present Recommended Practice. It seems likely, from the results of the study of actual rates of cooling in some mill containers, that some such fractures will be reported, but it is hoped (and expected) that such failures will be relatively few. It may be noted that controlled cooling does not prevent fractures arising from large inclusions near the tread (foreign material of some sort which was rolled into the rail), nor is it certain that controlled cooling will altogether do away with split heads, which may arise from other defects than shatter cracks.

4. Study of the Bend Test as an Acceptance Test for Rails

The bend test seems to have several features of superiority over the ordinary drop test now in use. Considerable study of this test has been carried out, and arrangements are being made to get a copy of the large amount of unpublished data on the bend test studies made in connection with the AREA investigation carried on in 1912–1919. These data are in the files of the Pennsylvania Railroad laboratories at Altoona, Pa. Preliminary plans have been developed for making bend tests on an hydraulic press available at one of the steel mills, if they are found to be desirable.

5. Records of Service Failures of Rails

Keeping in close touch with W. C. Barnes, engineer of tests, the test party is giving attention to all fissure failures of rails which come to notice. Usually for hot-bed cooled rails no special study is necessary, except in the case where the failure seems to have unusual features. Failures of controlled-cooled rails are always studied. Either a request is made for at least one of the broken pieces, or a member of the test party goes to inspect the fracture, if it can be arranged.

6. Batter Tests of End-Hardened Rails—Laboratory Tests

During the year laboratory tests of batter of rail ends have continued. These laboratory tests so far do not seem to be of sufficient sensitivity to differentiate between the different processes. In a general way it is indicated that processes which produce a hardness less than about 320 Brinell do not seem very effective, while hardnesses above 450 Brinell would seem to render the steel so brittle as to be in danger of chipping. For the study of the proper length and depth of hardening most suitable for service, results of the field tests for batter must be awaited.

Some tests have been made in the laboratory on the effect of the width of the gap at the joint. (1) For non-hardened rails, as the width of the joint gap is increased there is a marked increase in the amount of batter produced by, say, a million cycles of a 40,000-lb. wheel load. (2) For end-hardened rails whose hardness is not less than Rockwell C 35 (Brinell 325), variations in joint gap between the limits of zero and ¼ in. cause very little change in the amount of batter produced by a million cycles of a 40,000-lb. wheel load. These statements are true only provided the chamfering or slotting of rail ends is adequate to prevent chipping of the ends.

7. Batter Tests of End-Hardened Rails—Field Tests

Field tests of end batter of rails under service have been in progress since the spring of 1939. The tests are on a length of the westbound track of the Chesapeake & Ohio Railway a few miles north of Carey, Ohio. Nine hundred test rails constitute this length of track. Approximately 800 of the rails are end hardened, eight processes being used, while 100 rails are unhardened. Batter is measured by a slightly modified AREA 48-in. batter gage and a number of readings have been taken by the Graham recording profile gage. Hardness measurements have been made on many of the rails, using a light-weight portable Brinell apparatus designed by Professor H. R. Thomas and built in the Talbot Laboratory shops by M. K. Shafer. Three series of readings have been taken, one on freshly laid track, a second—regarded as the basic series, on the track after it had been alined and ready for service, and the third after it had been in service about six months. So far the batter developed is too slight to be used in drawing quantitative conclusions but the diminished batter on the end-hardened rails is quite obvious.

8. Miscellaneous Studies of Rail Steel

A study of the effect of gagging on the physical properties of rail steel is being made. Gagging of various degrees of severity is given to a rail in a testing machine, and the properties, of the specimens cut from the gagged portion, are contrasted with those cut from the portion which has not been gagged. So far specimens from a piece of rail which had been subjected to gagging almost to the point of fracture show an increase in tensile strength but a slight decrease in fatigue strength.

Tests of the properties of rail steel given different heat treatments have been made and indicate that by most of the heat treatments in end hardening rails both ductility and strength may be improved and also that the reduction of toughness observed in ordinary rail steel at low temperatures may be greatly mitigated.

II. WORK PLANNED FOR 1940

1. Temperature Limits for Controlled Cooled Rails

Further studies are planned at the various rail mills in the United States to determine ranges of rate of cooling which occur in different designs of rail-cooling containers, and to obtain data for study of methods of reducing the range of rate of cooling in any given container. Whether there may be drawn up a revision of the present Recommended Practice will presumably depend on the results of this study.

Some further tests of individual rail specimens under carefully measured temperatures are planned in which the specimens after removal from the cooling containers shall be very rapidly cooled. This is to get data to determine the necessity of leaving the rails in the cooling container until they have reached the temperature required by the present recommended practice. This question is of special importance in connection with rails rolled in northern mills in winter time.

2. Specifications for Bend Tests for Rails

A study of the data available at the Pennsylvania Railroad laboratory is to be made as soon as they become available, and it is hoped that those data may furnish a basis for writing specifications for a bend test for rails. If it seems desirable, bend tests may be conducted at a steel plant, to see whether an ordinary hydraulic press of 350-tons capacity can be readily rigged to make such tests, and whether the results are of sufficient accuracy.

3. Batter of End-Hardened Rails

Laboratory tests will be continued as a matter of routine. Some study of chipping with too hard rail ends or on rail joints with very small gap would seem to be worth while.

The field tests on the Chesapeake & Ohio near Carey, Ohio, will, of course, go on. Much more time will be required to reduce the field data than to get them. Some significant results may be expected by the end of the year 1940, although in all probability it will be desirable to extend the tests beyond that period.

4. Miscellaneous Studies

The test party will continue to keep in close touch with Mr. Barnes in connection with records of failures in service. Especial attention will be given to failures of controlled-cooled rails. The tests on the effect of gagging and the physical properties of rail steel are to be continued. Special attention will be given to fatigue tests and possibly to impact tests of unnotched specimens. It also would seem worth while to make some tests of thin, flat specimens cut from the cold rolled portion at the tread of the rail. A new fatigue testing machine recently purchased by the University of Illinois (from general university funds) is available for this work.

Tests of properties of rail steel given different heat treatments will be continued, although probably a smaller number of tests will be made than were made last year. A series of tests is being made as a part of a student's thesis and (except for machining specimens) without expense to the investigation, for a study of notch effects on impact tensile tests and fatigue tensile tests, and rail steel will be included as one of the materials. It is believed that this test may yield data of value to the investigation.

In general, it seems that during the year 1940 a larger proportion of the time and energy of the investigation will probably be spent in working up data obtained than has been done in the past. This is to be expected as any investigation develops.

Appendix B is submitted as a progress report, with the recommendation that the subject be continued.

Special Report

Since the adoption of the inclusion of the all-ingot nick and break test in the AREA Specifications for Open-Hearth Rails, there has been a widespread use of this method of testing of 1939 rail purchases.

In view of this fact, it was desirable to obtain data from the railroads indicating the results of this method of testing. A questionnaire was addressed to selected railroads and a summary of replies is shown on Sheets 1 and 2 of this appendix.

It is to be noted that the percentage of X-rails under the all-ingot test was materially reduced as compared with the results which would have been obtained if the former three-ingot test method had been used.

Summary of Replies to Questionnaire

Results of All Ingot Nick & Break Tests on Rail

Revised A.R.E.A. Rail Specifications - 1939

Sheet 1 of 2 Sheets.

November 28, 1939.

ROAD - - - - -	CMSt.P&P	CRI&P	C&O	DL&W	D&RGW	ERIE	IC	L&N	MP GULF	MP	NKP	NYNH&H	PM	PRR	READING
Sections - - -	112-131	112	131	131	112	112-131	112	100	90	90-112-131	112	112-131	112	131-152	130
Used 1939 Revised Spec.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
No. Ingots Rolled	7 723	9 353	6 058	1 446	2 259	2 995	4 981	634	768	5 312	1 784	4 388	802	5 003	477
No. Ingots Piped	979	739	653	40	175	229	215	24	29	410	160	248	70	353	4
Percent Ingots Piped	12.6	7.9	10.8	2.7	7.7	7.7	4.3	3.79	3.8	7.7	9.0	5.6	8.7	7.1	0.8
No. Top Rails Made X for Other Causes	278	217	136	9	39	18	52	18	0	93	55	6	40	-	0
Percent of Ingots Rolled	3.5	2.3	2.1	0.6	0.4	0.6	1.0	2.84	0	1.8	3.1	0.58	5.0	-	0
Total No. X-Rails under All Ingot Test	979	956	789	34	214	227	322	42	29	502	215	248	110	-	3
Total No. Rails which would have been classified as X-Rails if three Ingot Test had been used.	1 971	2 401	1 278	191	576	593	1 119	77	48	1 000	459	691	290	-	18
Percent X-Rails under All Ingot Test	2.15	1.6	2.3	0.5	1.3	1.4	1.1	.846	0.6	1.4	1.4	1.09	2.0	-	0.1
Percent X-Rails if three Ingot Test were used	4.33	3.8	3.8	2.7	4.6	3.6	3.9	1.55	0.9	2.8	3.1	3.04	5.3	-	0.7
How many finished Rails Classified as X-Rails showed no Pipe?	760	275	343	27	63	164	141	14	0	232	97	211	41	-	0
How many finished Rails showed Pipes, where test specimen showed no pipe?	123	143	136	5	56	18	56	18	0	93	-	18	40	-	2

Summary of Replies to Questionnaire

Results of All Ingot Nick & Break Tests on Rail

Revised A.R.E.A. Rail Specifications - 1939

Sheet 2 of 2 Sheets

November 28, 1939

ROAD - - - - - - Sections - - - -	So. Ry. 100-130	SP 112-131	UP 131	ACL	ATSF	B&O	B&M	CB&Q	C&NW	CNR	CPR	D&H	IRT	KCS	LV	MKT	N&W	NYCS
Used 1939 Revised Spec.	Yes	Yes	Yes	No	No	No	No	Special	Special	Special	No	No	No	No	No	No	No	No
No. Ingots Rolled	4 527	9 122	17 276	-	-	-	-				-	-	-	-	-	-	-	-
No. Ingots Piped	149	310	1 165	-	-	-	-				-	-	-	-	-	-	-	-
Percent Ingots Piped	3.2	3.4	6.7	-	-	-	-				-	-	-	-	-	-	-	-
No. Top Rails made X for Other Causes		80	271	-	-	-	-				-	-	-	-	-	-	-	-
Percent of Ingots Rolled		0.9	1.6	-	-	-	-				-	-	-	-	-	-	-	-
Total No. X-Rails under All Ingot Test		390	1 436	-	-	-	-	NO	NO	NO	-	-	-	-	-	-	-	-
Total No. Rails which would have been classified as X-Rails if three Ingot Test had been used.		720	3 128	-	-	-	-	DATA	DATA	DATA	-	-	-	-	-	-	-	-
Percent X-Rails under All Ingot Test		0.7	1.6	-	-	-	-				-	-	-	-	-	-	-	-
Percent X-Rails if three Ingot Test were used		1.3	3.5	-	-	-	-				-	-	-	-	-	-	-	-
How many Finished Rails Classified as X-Rails showed no pipe?		121	626	-	-	-	-				-	-	-	-	-	-	-	-
How many Finished Rails showed pipes, where test specimen showed no pipe?		80	271	-	-	-	-				-	-	-	-	-	-	-	-

Appendix C

(3) General Rail Failure Statistics For 1938

By W. C. Barnes, Engineer of Tests, Rail Committee

The rail failure statistics for the year ended December 31, 1938, appearing in this report, have been compiled in accordance with the standard method of basing the failure rates on mile-years of service in track.

The reported tonnages and track miles of rollings for 1933 and succeeding years, included in these statistics, are as follows:

Year Rolled	*Tons*	*Track Miles*
1933	205,264	1,089
1934	633,872	3,428
1935	375,054	2,054
1936	726,566	3,951
1937	777,193	4,221
Total	2,717,949	14,743

This compares with totals of 2,131,730 tons, or 11,608 track miles, of rail reported last year for the 1932 to 1936 rollings.

TABLE I - AVERAGE FAILURES PER 100 TRACK MILES - ALL MILLS
(Both service and detected failures are included)

Year Rolled	YEARS SERVICE				
	1	2	3	4	5
1908					398.1
1909				224.1	277.8
1910			124.0	152.7	198.5
1911		77.0	104.4	133.3	176.3
1912	28.9	32.1	49.3	78.9	107.1
1913	12.5	25.8	44.8	69.5	91.9
1914	8.2	19.8	32.9	50.9	74.0
1915	8.9	19.0	34.2	53.0	82.4
1916	11.8	29.2	47.7	70.6	105.4
1917	21.6	38.9	66.0	110.5	137.0
1918	8.9	27.6	54.0	92.8	125.4
1919	14.8	39.4	73.7	104.8	115.7
1920	14.2	32.4	63.1	84.5	119.6
1921	10.9	34.9	56.9	70.9	98.9
1922	15.9	34.8	55.2	80.4	110.0
1923	14.3	33.2	57.6	86.0	114.1
1924	14.0	33.4	58.3	82.0	110.7
1925	15.5	36.6	58.3	76.6	110.7
1926	17.1	41.2	64.6	102.6	131.3
1927	18.4	37.7	69.5	94.6	112.4
1928	11.0	28.0	45.8	57.4	76.4
1929	14.1	36.8	55.9	82.7	121.2
1930	7.8	12.8	22.4	37.6	60.0
1931	9.1	19.7	32.3	46.8	67.4
1932	4.5	11.8	21.2	39.6	64.1
1933	6.2	11.7	25.6	52.4	73.5
1934	4.6	13.6	19.3	25.9	
1935	4.2	9.6	16.3		
1936	4.2	7.3			
1937	3.3				

Table 1 shows the average failures per 100 track miles of rail in service which occurred in one to five years' service in the rail reported from rollings of 1933 to 1937, inclusive, from all mills, together with similar rates of older rollings taken from previous reports which include both Bessemer and open hearth rail. Both service and detected failures are included in this table.

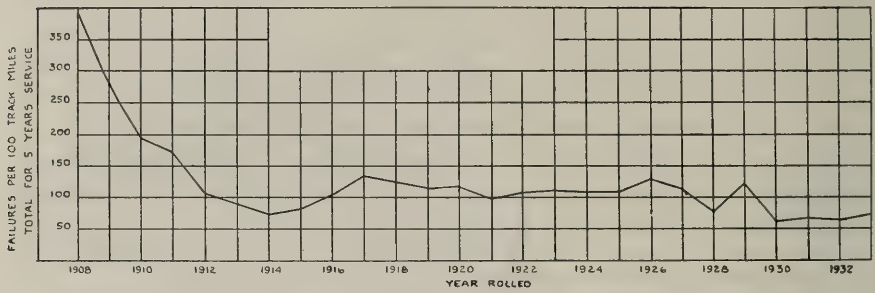


Fig. 1.—Service and Detected Rail Failures in the United States and Canada (Five Years' Service).

TABLE 2 - ACCUMULATED FAILURES AND FAILURE RATES FROM DATE ROLLED TO DEC. 31, 1938, BY MILLS, COMPUTED BY MILE YEARS OF RAIL IN SERVICE. ORIGINAL TRACK MILES ARE INCLUDED FOR INFORMATION ONLY.

		FAILURES TO DEC. 31, 1938						FAILURES TO DEC. 31, 1938				
		SERVICE		SERV. + DETECTED				SERVICE		SERV. + DETECTED		
YEAR ROLLED	ORIG'L TRK MLS	TOTAL	PR. 100 TRK MLS PR. YR.	TOTAL	PR. 100 TRK MLS PR. YRS	PR. 100 TRK MLS	ORIG'L TRK MLS	TOTAL	PR. 100 TRK MLS PR. YR.	TOTAL	PR. 100 TRK MLS PR. YR.	PR. 100 TRK MLS
			ALGOMA						DOMINION			
1933	--	-	--	-	--	--	--	-	--	-	--	--
1934	.94.39	33	8.78	40	10.63	--	--	-	--	-	--	--
1935	111.97	7	2.09	8	2.39	--	--	-	--	-	--	--
1936	114.51	19	8.23	19	8.23	--	41.111	0	0	0	0	--
1937	123.96	7	5.69	8	6.50	--	42.34	0	0	0	0	0-
			CARNEGIE						ENSLEY			
1933	241.47	46	3.90	95	13.40	40.50	150.78	105	14.40	299	40.96	204.70
1934	529.70	97	5.42	108	6.05	--	592.76	93	4.07	136	5.95	--
1935	254.88	12	1.57	20	2.62	--	470.70	34	2.57	42	3.17	--
1936	474.31	15	1.65	22	2.40	--	600.08	43	3.75	61	5.35	--
1937	529.28	24	5.00	25	5.20	--	685.03	16	2.30	17	2.50	--
			GARY						INLAND			
1933	207.27	63	6.41	251	25.52	128.10	107.64	9	1.75	17	3.30	16.51
1934	733.39	386	14.32	409	15.18	--	301.94	18	1.80	20	2.02	--
1935	493.25	134	9.34	215	14.98	--	176.73	14	2.88	14	2.88	--
1936	1,240.11	105	4.87	112	5.19	--	400.45	20	2.77	20	2.77	--
1937	1,100.65	54	3.75	55	5.27	--	378.47	8	2.24	8	2.24	--
			LACKAWANNA						MARYLAND			
1933	83.76	22	5.73	22	5.73	28.58	58.64	24	8.58	30	10.72	53.60
1934	326.61	42	3.26	45	3.50	--	150.93	13	2.41	13	2.41	--
1935	106.73	12	3.18	13	3.45	--	10.74	0	0	0	0	--
1936	191.13	14	3.71	16	4.24	--	41.30	0	0	0	0	--
1937	304.82	5	1.66	6	1.99	--	102.60	1	1.72	1	1.72	--
			MINNEQUA						STEELTON			
1933	132.25	20	3.03	20	3.03	15.16	107.34	0	0	1	0.24	1.18
1934	299.90	17	1.60	19	1.67	--	398.52	13	1.00	13	1.00	--
1935	295.30	10	1.17	10	1.17	--	136.62	4	1.00	4	1.00	--
1936	516.61	11	1.15	11	1.15	--	331.35	3	0.50	3	0.50	--
1937	620.95	4	0.70	4	0.70	--	333.35	8	2.48	8	2.48	--
		ALL MILLS (Excl. ALG. & DOM.)						ALL MILLS (Incl. ALG. & DOM.)				
1933	1,089.15	289	5.61	735	14.26	71.25	1,089.15	289	5.60	735	14.26	73.60
1934	3,333.30	679	5.66	763	6.35	--	3,427.69	712	5.75	803	6.48	25.93
1935	1,941.96	220	3.87	318	5.60	--	2,053.93	227	3.77	326	5.52	16.26
1936	3,795.34	211	3.09	245	3.53	--	3,950.96	230	3.17	264	3.64	7.29
1937	4,055.15	120	3.11	124	3.21	--	4,221.45	127	3.16	132	3.28	3.28
TOTALS	14,214.90	1519		2185			14,743.18	1585		2260		

The 1933 rollings, whose period of observation is now concluded, show an average rate of 73.5 failures per 100 track miles for the five year period, which is an increase of 9.4 over the rate reported last year for the 1932 rollings. The low rate of failure to date of the 1934 rollings indicates that their five-year record to be published next year will be appreciably better than that of the 1933 rollings.

Fig. 1 shows diagrammatically the five-year averages from Table 1.

Table 2 presents the accumulated failures and failure rates of rail from each of the mills for each of the rollings of 1933 and succeeding years. Service and service-plus-detected rates are shown separately.

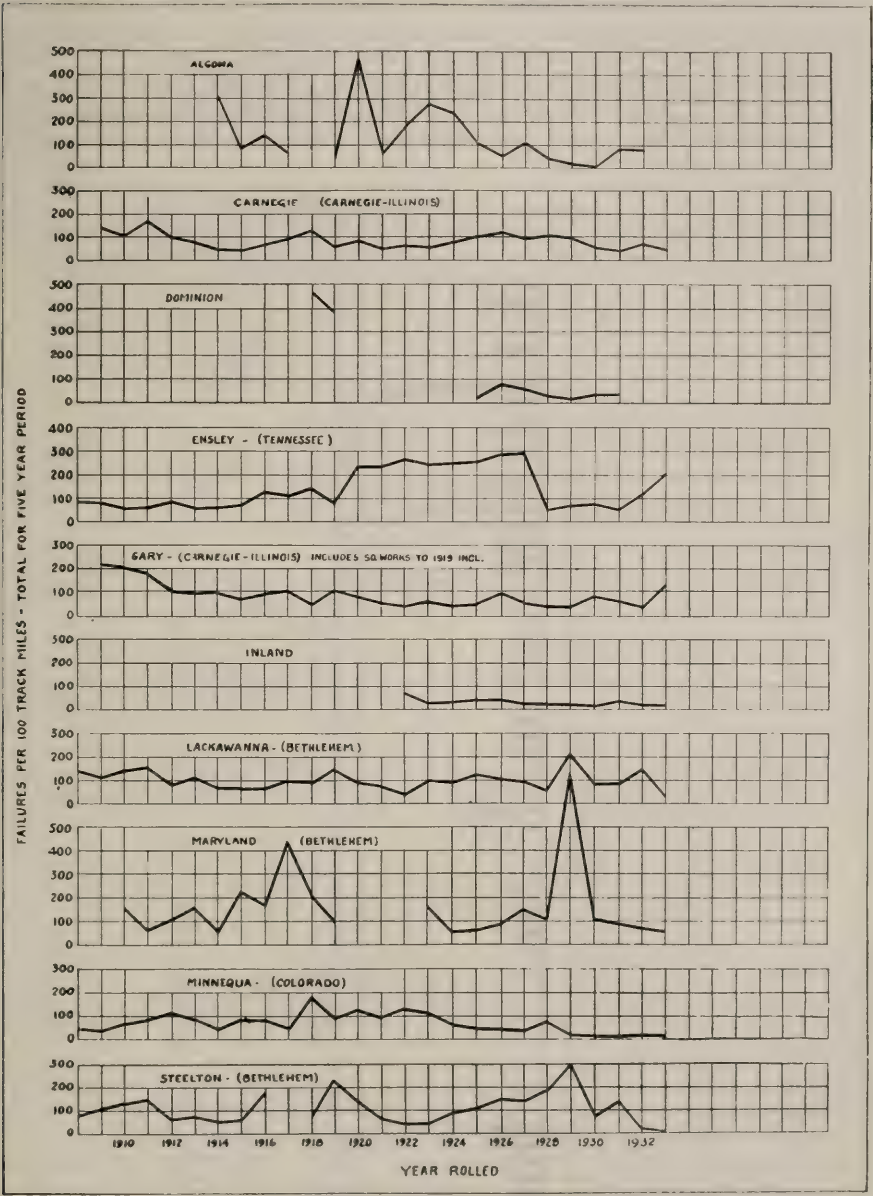
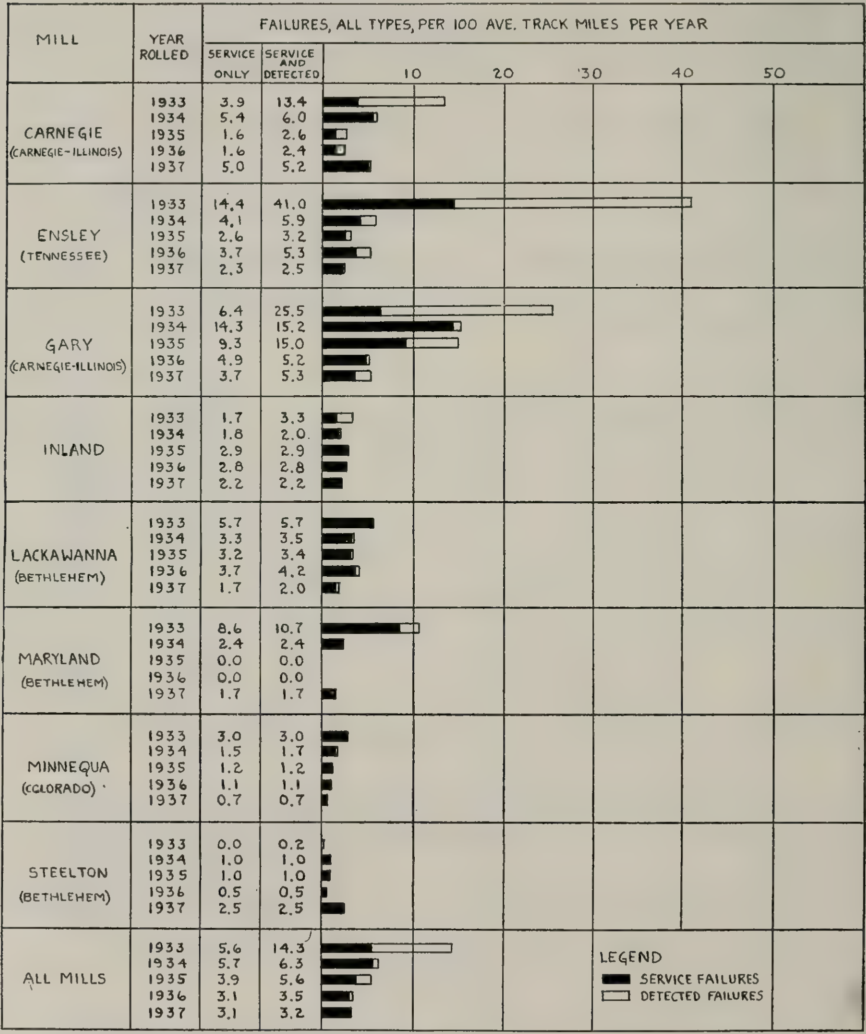


Fig. 2.—Record of Failures per 100 Track Miles for Five Years' Service for Rollings from 1908 to 1933 (Service and Detected Failures Included).

Fig. 2 shows diagrammatically the failure rates per 100 track miles of the 1933 rollings for five years' service, from Table 2, for combined service and detected failures. The five-year rates for earlier rollings are reproduced from previous reports.

Fig. 3 shows diagrammatically the Table 2 failure rates per 100 track miles per year, separately for service and service-plus-detected failures, for each of the 1933 and subsequent rollings, by mills, unweighted for traffic.

Fig. 4 shows diagrammatically the comparative performance of the mills from data underlying Fig. 3, except that average traffic density factors have been introduced to the final computations, using the method described on pages 369–370 of Vol. 32, AREA

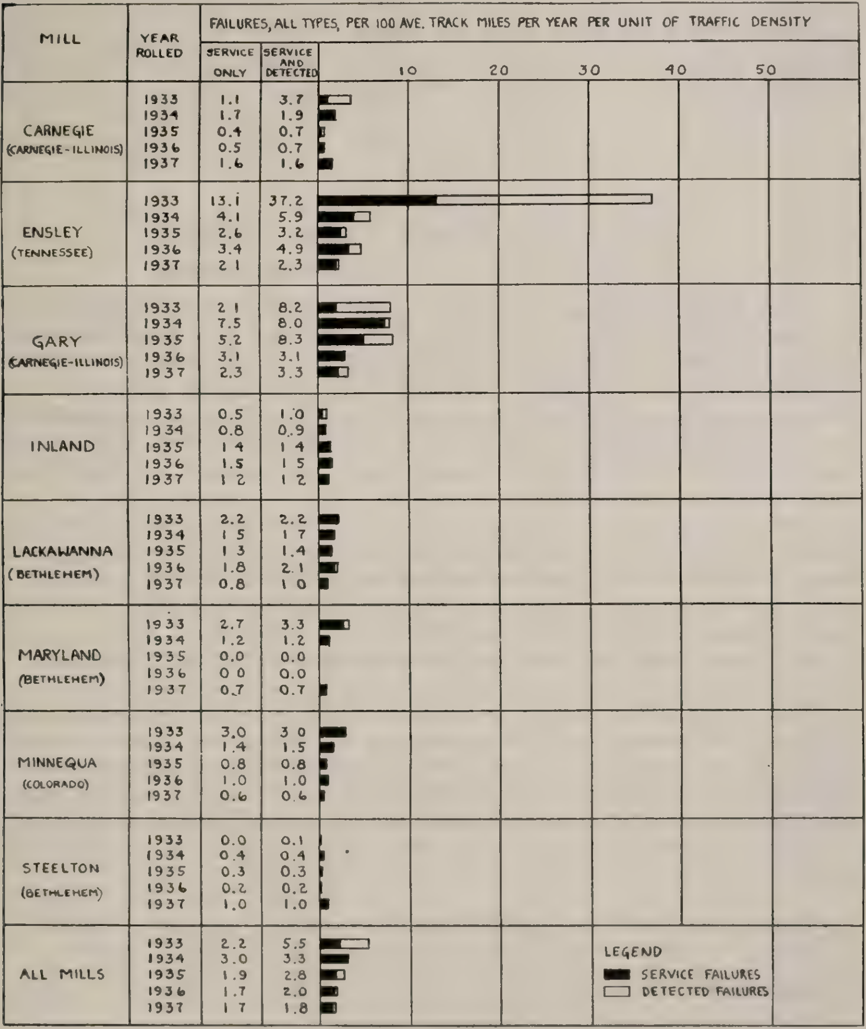


MILL	YEAR ROLLED	FAILURES, ALL TYPES, PER 100 AVE. TRACK MILES PER YEAR: SERVICE ONLY	SERVICE AND DETECTED
CARNEGIE (CARNEGIE-ILLINOIS)	1933	3.9	13.4
	1934	5.4	6.0
	1935	1.6	2.6
	1936	1.6	2.4
	1937	5.0	5.2
ENSLEY (TENNESSEE)	1933	14.4	41.0
	1934	4.1	5.9
	1935	2.6	3.2
	1936	3.7	5.3
	1937	2.3	2.5
GARY (CARNEGIE-ILLINOIS)	1933	6.4	25.5
	1934	14.3	15.2
	1935	9.3	15.0
	1936	4.9	5.2
	1937	3.7	5.3
INLAND	1933	1.7	3.3
	1934	1.8	2.0
	1935	2.9	2.9
	1936	2.8	2.8
	1937	2.2	2.2
LACKAWANNA (BETHLEHEM)	1933	5.7	5.7
	1934	3.3	3.5
	1935	3.2	3.4
	1936	3.7	4.2
	1937	1.7	2.0
MARYLAND (BETHLEHEM)	1933	8.6	10.7
	1934	2.4	2.4
	1935	0.0	0.0
	1936	0.0	0.0
	1937	1.7	1.7
MINNEQUA (COLORADO)	1933	3.0	3.0
	1934	1.5	1.7
	1935	1.2	1.2
	1936	1.1	1.1
	1937	0.7	0.7
STEELTON (BETHLEHEM)	1933	0.0	0.2
	1934	1.0	1.0
	1935	1.0	1.0
	1936	0.5	0.5
	1937	2.5	2.5
ALL MILLS	1933	5.6	14.3
	1934	5.7	6.3
	1935	3.9	5.6
	1936	3.1	3.5
	1937	3.1	3.2

Fig. 3.—Failure Rates from Date Rolled to December 31, 1938, by Mills, (Service and Detected Failure Rates Shown Separately).

Proceedings for 1931. No claim is made for the entire accuracy of this method of rating, but it does give more consideration to the service to which the rails from the respective mills are subjected than does the method of rating on which Fig. 3 is based.

Table 3 shows the average weights of rail from the various mills and from all mills included in these statistics.



MILL	YEAR ROLLED	SERVICE ONLY	SERVICE AND DETECTED
CARNEGIE (CARNEGIE-ILLINOIS)	1933	1.1	3.7
	1934	1.7	1.9
	1935	0.4	0.7
	1936	0.5	0.7
	1937	1.6	1.6
ENSLEY (TENNESSEE)	1933	13.1	37.2
	1934	4.1	5.9
	1935	2.6	3.2
	1936	3.4	4.9
	1937	2.1	2.3
GARY (CARNEGIE-ILLINOIS)	1933	2.1	8.2
	1934	7.5	8.0
	1935	5.2	8.3
	1936	3.1	3.1
	1937	2.3	3.3
INLAND	1933	0.5	1.0
	1934	0.8	0.9
	1935	1.4	1.4
	1936	1.5	1.5
	1937	1.2	1.2
LACKAWANNA (BETHLEHEM)	1933	2.2	2.2
	1934	1.5	1.7
	1935	1.3	1.4
	1936	1.8	2.1
	1937	0.8	1.0
MARYLAND (BETHLEHEM)	1933	2.7	3.3
	1934	1.2	1.2
	1935	0.0	0.0
	1936	0.0	0.0
	1937	0.7	0.7
MINNEQUA (COLORADO)	1933	3.0	3.0
	1934	1.4	1.5
	1935	0.8	0.8
	1936	1.0	1.0
	1937	0.6	0.6
STEELTON (BETHLEHEM)	1933	0.0	0.1
	1934	0.4	0.4
	1935	0.3	0.3
	1936	0.2	0.2
	1937	1.0	1.0
ALL MILLS	1933	2.2	5.5
	1934	3.0	3.3
	1935	1.9	2.8
	1936	1.7	2.0
	1937	1.7	1.8

Fig. 4.—Failure Rates from Year Rolled to December 31, 1938, by Mills, Altered by Traffic Density Factors (Service and Detected Failure Rates Shown Separately).

TABLE 3

AVERAGE WEIGHTS OF RAIL COMPILED FROM TONNAGES USED IN THIS REPORT

Mill	1933	1934	1935	1936	1937
Algoma	....	105.2	106.8	105.1	104.8
Dominion	....	....	....	99.9	99.8
Edgar Thomson (Carn)	128.2	129.3	128.8	126.3	127.2
Ensley (Tenn)	103.2	106.0	106.4	108.1	108.2
Gary (Ill)	119.3	116.0	116.2	116.7	116.2
Inland	120.1	117.5	118.6	119.1	115.8
Lackawanna (Beth)	125.3	120.5	118.9	119.1	117.7
Maryland (Beth)	122.9	120.8	130.8	127.1	130.5
Minnequa (Colo)	111.1	115.6	116.9	114.8	111.3
Steelton (Beth)	130.1	124.0	122.3	125.3	136.6
All Mills	119.8	117.6	116.1	116.9	117.1

Appendix D

(3) Transverse Fissure Failure Statistics

By W. C. Barnes, Engineer of Tests, Rail Committee

These statistics constitute a cumulative record of transverse fissure failures that have been reported, up to and including December 31, 1938. They include all fissured rails reported, whether located by actual breakage in track or detected before breakage by inspection or test. This total, however, does not represent all such failures that have occurred for the reason that while the records of some roads have been cumulative for over 20 years, those of other roads are of more recent origin and furthermore some roads do not report such failures. Compound fissures and horizontal split heads (horizontal fissures) are not included.

Table 1 corresponds with Table 1 of last year's report and shows separately the number of service and detected transverse fissure failures classified by roads and by year failed. It includes data only from such roads as have consistently reported failures over a long period of years and have also reported separately the service and detected failures since the introduction of detection methods in 1929. The total failures on any one road or on all roads during any given year can be obtained by adding the corresponding figures for the service failures and detected failures appearing in this table.

Table 1 differs from Table 1 of last year's report in that service failures which occurred in the years 1919 to 1928, inclusive, are no longer shown separately but are included in the column headed "Prior". The Total column for Service Failures does not now include the failures listed under heading "Prior", as all roads did not start reporting at the same time. Additional explanations will be found in footnotes to the table.

The total fissure failures reported in 1938, compared with the 1937 revised totals, are:

	Service	*Detected*	*Total*
1937	6,626	11,161	17,787
1938	5,293	10,844	16,137
Reduction in 1938	1,333	317	1,650

Fig. 1 presents graphically the fissure failures by year failed from Table 1. The solid line shows the service failures; the broken line, the detected failures only; and the dotted line, the total service-plus-detected failures. Despite the large number of fissured rails detected and removed from track before service failures can occur, the service failures continue excessive.

TABLE 1.—TRANSVERSE FISSURE FAILURES BY RAILROAD AND YEAR FAILED[a]

Roads	SERVICE FAILURES											Total 1929–38 incl.	DETECTED FAILURES[b]										
	Prior[c]	*1929*	*1930*[d]	*1931*	*1932*	*1933*	*1934*	*1935*	*1936*	*1937*	*1938*		*1929*	*1930*	*1931*	*1932*	*1933*	*1934*	*1935*	*1936*	*1937*	*1938*	*Total*
A T & S F (e)	1,177	91	142	114	84	64	46	35	46	92	43	757	0	0	0	0	13	77	121	59	247	194	711
A C L	47	25	21	29	37	15	33	48	62	102	66	438	0	66	0	0	69	0	0	159	180	251	725
Ban. & Aroos.	13	4	7	2	1	1	0	0	0	0	0	15	0	0	0	0	0	0	0	0	0	0	0
B & M	368	34	35	22	33	17	24	18	12	14	28	237	0	17	0	19	45	17	0	241	207	45	591
B & O	2,097	469	372	506	383	397	328	356	325	431	382	3,949	53	0	0	182	217	308	618	630	652	807	3,467
C P	942	108	138	106	89	88	94	121	122	137	114	1,117	0	0	351	214	474	834	899	999	1,502	1,239	6,512
C of G A	428	92	80	42	74	56	81	54	64	55	59	657	0	80	0	107	18	136	101	96	119	110	767
C of N J	92	95	73	59	40	61	85	58	110	112	90	783	0	35	111	0	0	0	0	0	0	0	146
C & E I	26	41	18	18	28	39	23	14	18	22	23	244	28	0	59	0	74	43	65	29	65	77	440
C & O (g)	907	258	181	239	330	280	316	300	227	310	187	2,628	22	376	667	323	978	584	1,262	1,392	891	923	7,418
C & N W	195	62	101	86	110	81	99	69	68	41	38	755	16	31	110	218	110	341	155	355	317	294	1,947
C M St P & P	102	11	26	45	105	125	99	71	74	53	46	655	43	0	49	0	156	179	247	197	357	288	1,516
C R I & P	632	123	111	116	131	139	136	97	135	121	98	1,207	20	0	18	93	13	274	62	132	344	366	1,322
D L & W (h)	1,739	139	98	64	102	82	65	76	90	75	72	863	0	0	0	0	0	173	244	229	454	461	1,561
Erie (j)	641	235	156	175	181	179	187	171	167	229	123	1,803	27	7	4	0	75	0	165	0	166	0	444
G N	279	175	189	141	126	128	143	179	246	276	215	1,818	0	25	0	0	6	144	114	88	69	92	538
I C	4,092	597	439	310	281	245	275	364	467	540	515	4,033	25	126	204	217	273	108	284	314	447	557	2,555
I H B	7	0	0	0	0	0	0	3	2	6	0	11	0	0	0	0	0	0	0	0	0	2	2
L & H R	75	8	3	11	3	4	2	0	1	5	6	43	0	0	0	0	0	0	0	0	0	0	0
L & N E	33	0	0	6	3	2	7	0	0	6	1	25	0	0	0	0	0	16	0	0	24	0	40
L V	556	60	39	22	17	34	30	31	22	28	52	335	0	0	78	0	0	140	0	140	0	0	358
L & N	1,628	456	285	268	220	182	215	181	253	229	178	2,467	101	165	0	0	358	19	341	488	577	530	2,579
M K T	164	30	31	32	30	17	20	33	39	30	35	297	10	12	29	76	31	98	74	77	167	169	743
M & O	107	18	26	32	42	24	25	28	45	76	55	371	4	0	0	0	0	1	0	0	0	0	5
N C & St L	68	34	22	50	42	58	20	19	50	36	19	350	0	2	0	0	0	40	45	17	42	70	216
N Y C Sys. (k)	2,615	444	340	306	299	306	272	318	381	361	389	3,416	27	107	83	182	253	114	191	322	322	428	2,029
N Y N H & H	247	51	40	25	24	40	59	34	37	48	39	397	17	67	159	106	101	100	82	60	101	92	885
N Y O & W	121	63	60	48	54	67	34	34	21	37	55	473	0	0	1	4	0	0	0	0	0	0	5
N & W	146	25	43	41	29	50	33	23	38	36	22	340	0	20	0	5	0	74	0	0	84	45	228
N P	864	160	131	171	160	126	169	168	171	259	213	1,728	48	0	0	0	81	19	324	173	292	246	1,183
P R R (l)	10,652	584	572	426	317	344	439	450	508	634	477	4,751	0	192	378	378	818	429	1,043	700	751	832	5,521
P M (m)	----	----	----	----	----	----	----	----	----	4	1	5	----	----	----	----	----	----	----	----	20	5	25
Reading	479	53	57	100	111	111	160	166	162	186	164	1,270	0	0	0	0	0	0	0	0	0	0	0
R F & P	0	1	0	1	3	5	4	4	2	4	3	27	3	0	0	0	36	0	67	44	53	52	255
Rutland	6	2	3	1	0	1	0	1	1	1	1	11	0	0	0	7	0	0	3	0	0	0	10
S P (Pac. Lines)	2,143	500	458	331	322	269	208	200	324	481	394	3,487	0	131	251	142	374	580	455	767	629	637	3,966
U P (n)	2,907	438	497	495	535	517	936	1,003	1,176	1,443	923	7,963	34	0	137	157	321	660	1,361	1,437	1,996	2,032	8,135
Virginian	10	12	7	24	24	28	33	30	23	36	34	251	0	0	0	0	0	0	0	0	0	0	0
West. Md	552	57	255	148	94	94	62	87	116	70	133	1,116	0	0	0	0	0	106	0	0	86	0	192
All Roads(o)	37,157	5,555	5,056	4,612	4,464	4,276	4,762	4,844	5,605	6,626	5,293	51,093	478	1,459	2,689	2,430	4,894	5,614	8,323	9,145	11,161	10,844	57,037

Notes—

(a) Roads not reporting service and detected failures separately are not included.
(b) Detection methods first used to any extent in 1929.
(c) Prior includes all fissures reported as failed prior to 1929.
(d) 1930 data covers 11 months only, account change in fiscal year.
(e) AT&SF 1937 data includes additional failures submitted by road.
(f) BR&P included with B&O. B&O 1937 service data includes additional failures submitted by road.
(g) HV included with C&O.
(h) DL&W 1935, 1936 & 1937 service data includes additional failures submitted by road.
(j) Erie 1930, 1931, 1935 & 1937 detected data includes additional failures submitted by road.
(k) NYC System includes B&A, CCC&St.L., MC, NYC(e) and NYC(w).
(l) LI RR included with PRR. PRR 1937 service data includes additional failures submitted by road.
(m) PM began reporting with 1937 failures.
(n) LA&SL included with UP.
(o) Southern System failures have been deleted as carrier has discontinued reporting.

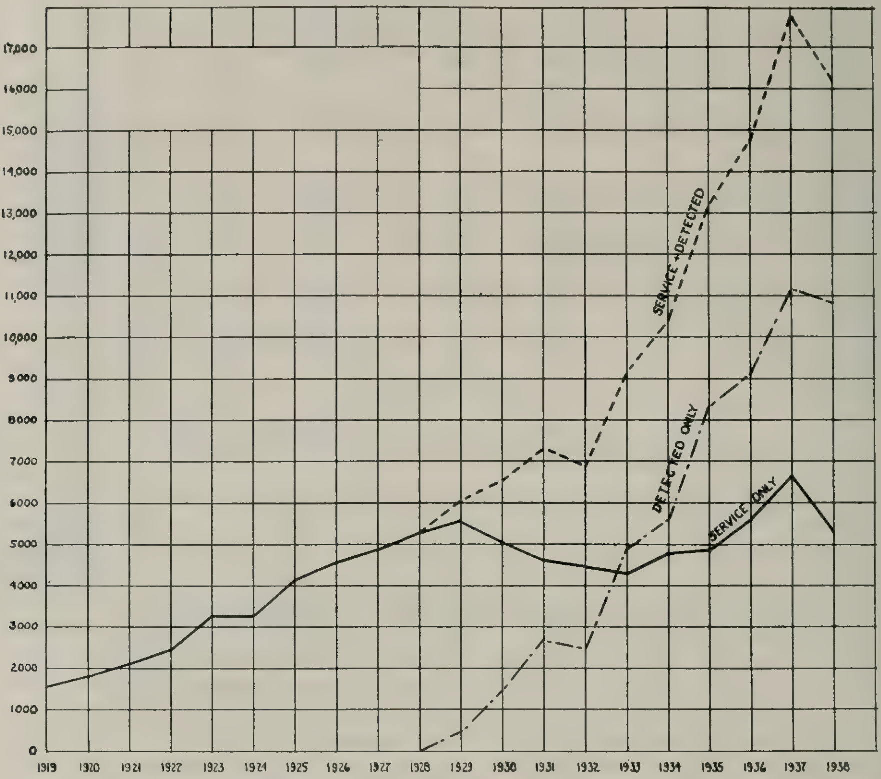


Fig. 1.—Total Fissure Failures Reported Each Year (1930 Includes 11 Months Only).

Table 2 shows all transverse fissure failures, service plus detected, reported by all roads for each year's rollings from each mill accumulated from the year rolled to December 31, 1938. These data are unweighted for tonnage output of the mills, for density of traffic or for years of service. Reports from all roads are included and hence Table 2 includes a total number of failures, which is in excess of the total included in Table 1. This table is most useful in comparing the failures in the various years' rollings from any one mill. Fissure failures reported since 1924, as occurring in the first year of service, are as follows:

29 Failures in 1925 from 1925 Rollings, All Mills
50 " " 1926 " 1926 " " "
114 " " 1927 " 1927 " " "
58 " " 1928 " 1928 " " "
106 " " 1929 " 1929 " " "
33 " " 1930 " 1930 " " "
32 " " 1931 " 1931 " " "
3 " " 1932 " 1932 " " "
0 " " 1933 " 1933 " " "
0 " " 1934 " 1934 " " "
3 " " 1935 " 1935 " " "
3 " " 1936 " 1936 " " "
1 " " 1937 " 1937 " " "
0 " " 1938 " 1938 " " "

TABLE 2 - ACCUMULATED TRANSVERSE FISSURE FAILURES REPORTED TO DEC. 31, 1938 BY YEAR ROLLED AND BY MILL
(Includes Fissured Rails Detected Before Actual Failure in Track)

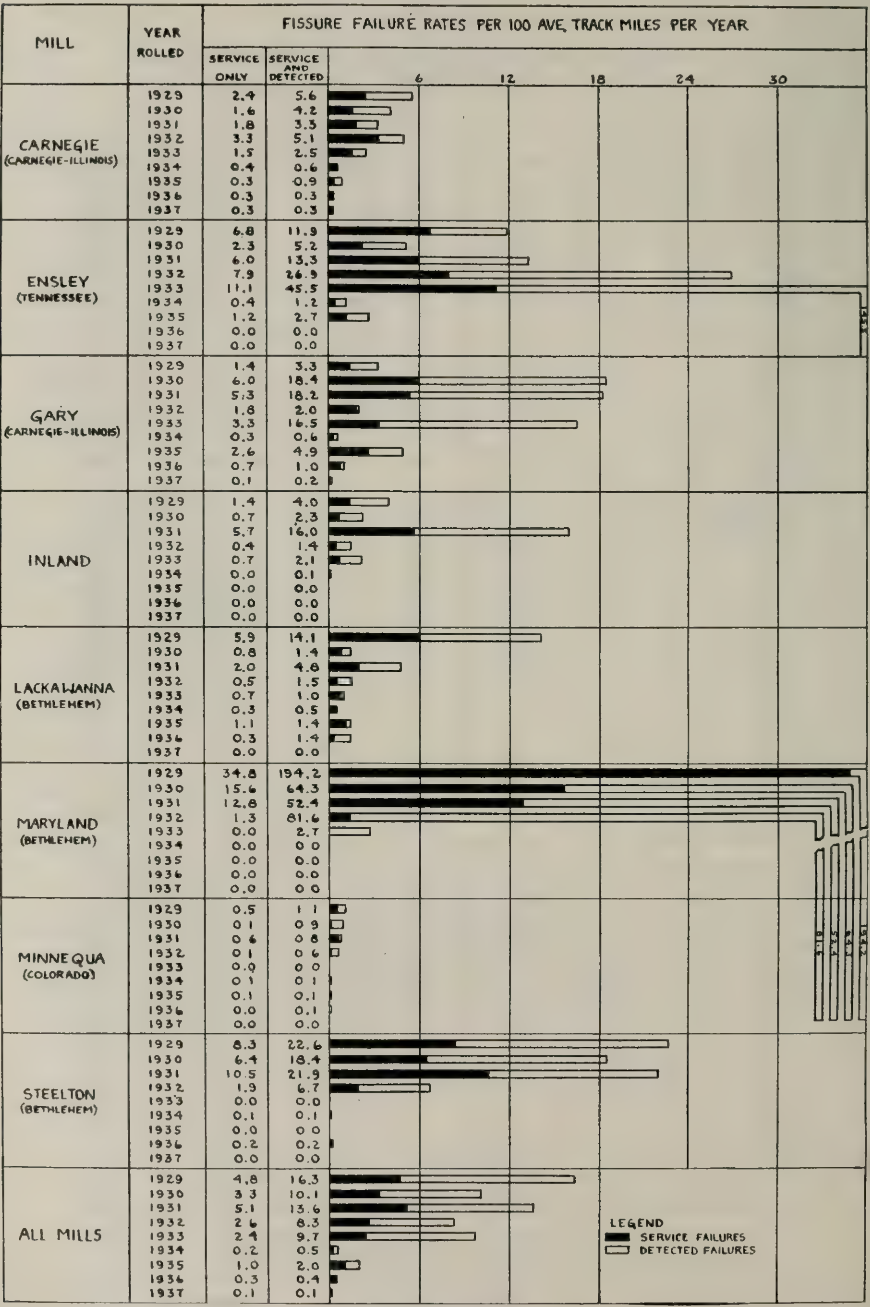
	Unknown & Discont'd Mills*			Algoma			Carnegie			Colorado		
Yr.Rolled	Prior	1938	Total	Prior	1938	Total	Prior	1938	Total	Prior	1938	Total
Unknown	284	21	305	14	3	17	73	10	83	36	2	38
Prior	10797	212	11009	3319	322	3641	1706	75	1781	5715	727	6442
1923	167	4	171	868	100	968	259	11	270	105	12	117
1924	66	1	67	1312	263	1575	261	12	273	109	26	135
1925	57	12	69	204	57	261	358	17	375	174	30	204
1926	34	9	43	124	42	166	769	56	825	223	102	325
1927	30	5	35	421	113	534	666	54	720	214	49	263
1928	2	5	7	601	250	851	818	121	939	286	91	377
1929	0	3	3	54	32	86	608	68	676	102	47	149
1930	1	0	1	3	0	3	243	52	295	31	18	49
1931	0	0	0	18	3	21	115	26	141	7	12	19
1932	0	1	1	28	11	39	36	13	49	6	3	9
1933	1	0	1	0	0	0	23	15	38	0	0	0
1934	0	0	0	24	6	30	6	7	13	0	1	1
1935	0	0	0	0	0	0	1	5	6	4	0	4
1936	0	0	0	0	0	0	0	3	3	0	1	1
1937	0	0	0	0	0	0	0	1	1	1	0	1
1938	0	0	0	0	0	0	0	0	0	0	0	0
TOTALS	11439	273	11712	6990	1202	8192	5942	546	6488	7013	1121	8134

	Dominion			Gary			Inland			Lackawanna		
Yr.Rolled	Prior	1938	Total	Prior	1938	Total	Prior	1938	Total	Prior	1938	Total
Unknown	4	0	4	211	11	222	17	5	22	42	4	46
Prior	561	21	582	27390	2637	30027	326	38	364	6851	312	7163
1923	0	0	0	2687	364	3051	273	40	313	812	56	868
1924	0	0	0	2042	386	2428	744	150	894	391	38	429
1925	456	125	581	1568	428	1996	499	118	617	705	54	759
1926	307	78	385	2404	494	2898	788	154	942	1231	139	1370
1927	14	18	32	1671	377	2048	264	92	356	1232	140	1372
1928	10	8	18	471	190	661	272	71	343	558	61	619
1929	8	10	18	359	139	498	132	37	169	861	247	1108
1930	4	15	19	1398	493	1891	48	24	72	41	13	54
1931	0	0	0	620	276	896	143	79	222	43	47	90
1932	0	0	0	13	11	24	2	4	6	3	7	10
1933	0	0	0	117	;48	165	4	5	9	1	2	3
1934	0	0	0	11	13	24	0	2	2	3	3	6
1935	0	0	0	25	57	82	0	1	1	2	3	5
1936	0	0	0	6	10	16	0	0	0	1	3	4
1937	0	0	0	0	2	2	0	0	0	0	0	0
1938	0	0	0	0	0	0	0	0	0	0	0	0
TOTALS	1364	275	1639	40993	5936	46929	3512	820	4332	12777	1129	13906

	Maryland			Steelton			Tennessee			ALL MILLS		
Yr.Rolled	Prior	1938	Total	Prior	1938	Total	Prior	1938	Total	Prior	1938	Total
Unknown	18	1	19	28	6	34	269	17	286	996	80	1076
Prior	4540	104	4644	2354	119	2473	6245	431	6676	69802	4998	74800
1923	10	0	10	262	26	288	907	133	1040	6350	746	7096
1924	60	13	73	608	51	659	1884	261	2145	7477	1201	8678
1925	368	15	383	566	71	637	2326	271	2597	7261	1198	8479
1926	439	55	494	865	134	999	2269	172	2441	9453	1435	10888
1927	1125	116	1241	1108	164	1272	1520	171	1691	8265	1299	9564
1928	982	120	1102	1512	299	1811	373	64	437	5885	1280	7165
1929	5387	699	6086	1326	158	1484	729	150	879	9566	1590	11156
1930	714	243	957	693	80	773	280	66	346	3456	1004	4460
1931	333	122	455	516	98	614	435	172	607	2230	835	3065
1932	75	49	124	14	1	15	242	101	343	419	201	620
1933	17	11	28	0	0	0	174	40	214	337	121	458
1934	0	0	0	1	0	1	5	16	21	50	48	98
1935	0	1	1	0	0	0	16	11	27	48	78	126
1936	1	0	1	1	0	1	1	2	3	10	19	29
1937	0	0	0	0	0	0	0	0	0	1	3	4
1938	0	0	0	0	0	0	0	0	0	0	0	0
TOTALS	14069	1549	15618	9854	1207	11061	17675	2078	19753	131626	16136	147762

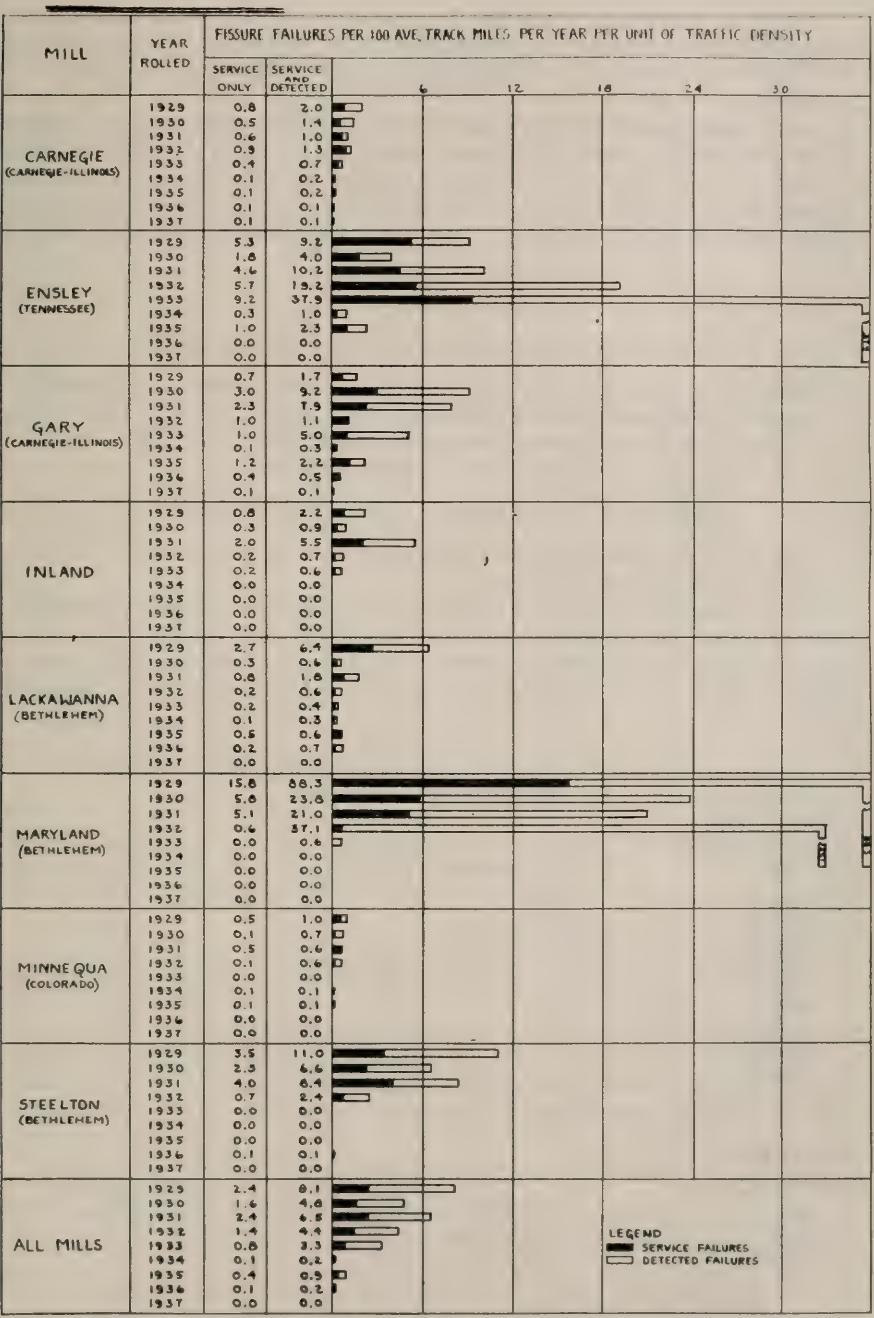
Notes:* Discontinued mills included with Unknown are Cambria, Saucon, German and Lorain

The above chart does not include additional failures reported by the Erie too late for inclusion. They will be included in next year's report.



MILL	YEAR ROLLED	SERVICE ONLY	SERVICE AND DETECTED
CARNEGIE (CARNEGIE-ILLINOIS)	1929	2.4	5.6
	1930	1.6	4.2
	1931	1.8	3.3
	1932	3.3	5.1
	1933	1.5	2.5
	1934	0.4	0.6
	1935	0.3	0.9
	1936	0.3	0.3
	1937	0.3	0.3
ENSLEY (TENNESSEE)	1929	6.8	11.9
	1930	2.3	5.2
	1931	6.0	13.3
	1932	7.9	26.9
	1933	11.1	45.5
	1934	0.4	1.2
	1935	1.2	2.7
	1936	0.0	0.0
	1937	0.0	0.0
GARY (CARNEGIE-ILLINOIS)	1929	1.4	3.3
	1930	6.0	18.4
	1931	5.3	18.2
	1932	1.8	2.0
	1933	3.3	16.5
	1934	0.3	0.6
	1935	2.6	4.9
	1936	0.7	1.0
	1937	0.1	0.2
INLAND	1929	1.4	4.0
	1930	0.7	2.3
	1931	5.7	16.0
	1932	0.4	1.4
	1933	0.7	2.1
	1934	0.0	0.1
	1935	0.0	0.0
	1936	0.0	0.0
	1937	0.0	0.0
LACKAWANNA (BETHLEHEM)	1929	5.9	14.1
	1930	0.8	1.4
	1931	2.0	4.8
	1932	0.5	1.5
	1933	0.7	1.0
	1934	0.3	0.5
	1935	1.1	1.4
	1936	0.3	1.4
	1937	0.0	0.0
MARYLAND (BETHLEHEM)	1929	34.8	194.2
	1930	15.6	64.3
	1931	12.8	52.4
	1932	1.3	81.6
	1933	0.0	2.7
	1934	0.0	0 0
	1935	0.0	0.0
	1936	0.0	0.0
	1937	0.0	0 0
MINNEQUA (COLORADO)	1929	0.5	1 1
	1930	0 1	0 9
	1931	0 6	0 8
	1932	0 1	0 6
	1933	0.0	0 0
	1934	0 1	0 1
	1935	0.1	0.1
	1936	0.0	0.1
	1937	0.0	0.0
STEELTON (BETHLEHEM)	1929	8.3	22.6
	1930	6.4	18.4
	1931	10.5	21.9
	1932	1.9	6.7
	1933	0.0	0.0
	1934	0.1	0.1
	1935	0.0	0 0
	1936	0.2	0.2
	1937	0.0	0.0
ALL MILLS	1929	4.8	16.3
	1930	3 3	10.1
	1931	5.1	13.6
	1932	2 6	8.3
	1933	2 4	9.7
	1934	0.2	0.5
	1935	1.0	2.0
	1936	0.3	0.4
	1937	0.1	0.1

Fig. 2.—Fissure Failure Rates from Date Rolled to December 31, 1938, by Mills (Service and Detected Failures Shown Separately).



MILL	YEAR ROLLED	SERVICE ONLY	SERVICE AND DETECTED
CARNEGIE (CARNEGIE-ILLINOIS)	1929	0.8	2.0
	1930	0.5	1.4
	1931	0.6	1.0
	1932	0.9	1.3
	1933	0.4	0.7
	1934	0.1	0.2
	1935	0.1	0.2
	1936	0.1	0.1
	1937	0.1	0.1
ENSLEY (TENNESSEE)	1929	5.3	9.2
	1930	1.8	4.0
	1931	4.6	10.2
	1932	5.7	19.2
	1933	9.2	37.9
	1934	0.3	1.0
	1935	1.0	2.3
	1936	0.0	0.0
	1937	0.0	0.0
GARY (CARNEGIE-ILLINOIS)	1929	0.7	1.7
	1930	3.0	9.2
	1931	2.3	7.9
	1932	1.0	1.1
	1933	1.0	5.0
	1934	0.1	0.3
	1935	1.2	2.2
	1936	0.4	0.5
	1937	0.1	0.1
INLAND	1929	0.8	2.2
	1930	0.3	0.9
	1931	2.0	5.5
	1932	0.2	0.7
	1933	0.2	0.6
	1934	0.0	0.0
	1935	0.0	0.0
	1936	0.0	0.0
	1937	0.0	0.0
LACKAWANNA (BETHLEHEM)	1929	2.7	6.4
	1930	0.3	0.6
	1931	0.8	1.8
	1932	0.2	0.6
	1933	0.2	0.4
	1934	0.1	0.3
	1935	0.5	0.6
	1936	0.2	0.7
	1937	0.0	0.0
MARYLAND (BETHLEHEM)	1929	15.8	88.3
	1930	5.8	23.8
	1931	5.1	21.0
	1932	0.6	37.1
	1933	0.0	0.6
	1934	0.0	0.0
	1935	0.0	0.0
	1936	0.0	0.0
	1937	0.0	0.0
MINNEQUA (COLORADO)	1929	0.5	1.0
	1930	0.1	0.7
	1931	0.5	0.6
	1932	0.1	0.6
	1933	0.0	0.0
	1934	0.1	0.1
	1935	0.1	0.1
	1936	0.0	0.0
	1937	0.0	0.0
STEELTON (BETHLEHEM)	1929	3.5	11.0
	1930	2.5	6.6
	1931	4.0	8.4
	1932	0.7	2.4
	1933	0.0	0.0
	1934	0.0	0.0
	1935	0.0	0.0
	1936	0.1	0.1
	1937	0.0	0.0
ALL MILLS	1929	2.4	8.1
	1930	1.6	4.8
	1931	2.4	6.5
	1932	1.4	4.4
	1933	0.8	3.3
	1934	0.1	0.2
	1935	0.4	0.9
	1936	0.1	0.2
	1937	0.0	0.0

Fig. 3.—Fissure Failure Rates from Date Rolled to December 31, 1938, by Mills, Altered by Traffic Density Factors (Service and Detected Failures Shown Separately).

Fig. 2 is a mill rating chart which shows separately the service and detected transverse fissure failure rates per 100 average track miles per year of each of the 1929 to 1937 rollings, inclusive, of each mill from the date rolled to December 31, 1938, unweighted for traffic.

Fig. 3 shows graphically the average rates of failure, by mills, from Fig. 2, modified by the application of average traffic density factors, the derivation of which is explained on pages 369–70 of Vol. 32 of the AREA Proceedings for 1931. Owing to the necessity of using factors obtained from average traffic per mile of road, instead of actual traffic over the particular rails in question, this chart can be considered only as an approximation.

Appendix E

(3) Controlled Cooled and Brunorized Rail

Compilation of Statistics for Determining the Performance of Controlled Cooled and Brunorized Rail in Service With Respect to Rail Failures, With the View Toward Evaluating the Higher Price Paid for Treated Than for Untreated Rails

By W. C. Barnes, Engineer of Tests, Rail Committee

Data are being accumulated to assist in determining the performance of controlled cooled and Brunorized rail in service.

Table 2 gives the tonnages of all such contract rail, from all mills, purchased by roads represented on the Rail committee, as reported to June 30, 1939. It includes a total of 2,106,046 tons of controlled cooled rail, 93,629 tons of Brunorized rail, making a total of 2,199,675 tons. It should be noted that the report this year covers tonnage of

TABLE 1

FAILURE DATA IN CONTROLLED COOLED OR BRUNORIZED RAIL—SUMMARY BY MILLS—ALL ROLLINGS

Kind of Rail

Controlled Cooled:

Mill	*All Rollings*	*Trans. Fiss.*	*Head*	*Web*	*Base*	*Breaks (Misc.)*	*Total*
Algoma	All “	0	19	2	21	9	51
Carnegie	“ “	0	1	5	1	2	9
Colorado	“ “	0	3	0	1	2	6
Dominion	“ “	0	13	3	8	10	34
Gary	“ “	0	5	6	11	10	32
Inland	“ “	0	5	1	10	16	32
Lackawanna	“ “	0	4	0	1	0	5
Steelton	“ “	0	4	3	1	3	11
Tennessee	“ “	0	11	25	1	7	44
All Mills—All Rollings		0	65	45	55	59	224

Kind of Rail

Brunorized:

Mill	*All Rollings*	*CF or Trans. Fiss.*	*Head*	*Web*	*Base*	*Breaks (Misc.)*	*Total*
Gary	1936 Rolling	0	1	0	1	1	3
Gary	1937 “	3 T.F.	2	0	3	8	16
Gary Mill—All Rollings		*3	3	0	4	9	19

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* These three verified fissures from Gary 1937 rolling are from steel which was rolled before the modification of the Brunorized process on April 27, 1938.

TABLE 2

TONNAGE OF CONTROLLED COOLED AND BRUNORIZED CONTRACT RAIL PURCHASED TO JUNE 30, 1939

Road	*Controlled Cooled*	*Brunorized*	*Total*
AT&SF	202,260	3,571	205,831
ACL	0	0	0
B&O	5,000	0	5,000
B&M	10,080	0	10,080
CPR	147,246	0	147,246
CNR	148,821	0	148,821
C&NW	53,678	15,106	68,784
C&O	143,211	0	143,211
CB&Q	75,380	11,822	87,202
CMStP&P	43,349	25,463	68,812
CRI&P	82,984	0	82,984
D&H	19,277	0	19,277
D&RGW	31,581	0	31,581
DL&W	33,138	0	33,138
Erie	71,674	0	71,674
GN	26,195	9,503	35,698
IC	32,991	5,555	38,546
IRT Co	9,409	0	9,409
KCS	8,347	4,790	13,137
LV	4,355	0	4,355
L&N	63,162	0	63,162
MKT	0	204	204
M.P.	80,439	0	80,439
MeCent.	4,749	0	4,749
NYC Sys.	128,731	13,117	141,848
NYC&StL	35,021	0	35,021
NYNH&H	27,937	0	27,937
N&W	40,206	0	40,206
NP	76,577	0	76,577
PM	22,334	0	22,334
PRR	132,582	0	132,582
Reading	2,787	0	2,787
SP	184,006	0	184,006
Sou. Sys.	67,914	0	67,914
UP	90,625	4,498	95,123
Total Tons	2,106,046	93,629	2,199,675

contract rail purchased, whereas last year's report, showed the tonnages of contract rail laid in track.

The latest contract rollings included are those of 1939 and the earliest are as follows: Dominion—January, 1931; Algoma—December, 1933; Steelton—March, 1935; Inland—April, 1935; Lackawanna—May, 1935; Carnegie—October, 1935; Ensley—February, 1936; Gary CC—April, 1936; Gary Brunorized—October, 1936. (Revised process—April 27, 1938).

Table 1 lists all failures that have been reported to November 27, 1939, in the rail included in Table 2.

Despite the large tonnages of these special rails now under observation, few failures of all types have been reported to November 27, 1939, the date of this compilation, and no transverse fissure failures verified as such have been reported as occurring in controlled cooled rail, and none in Brunorized rail since that process was modified on April 27, 1938 to provide for holding the rails at a temperature of 800 to 1,000 deg. F. for 2½ hours before charging them into the Brunorizing furnace.

(3) The AAR Detector Car

By W. C. Barnes, Engineer of Tests, Rail Committee

The AAR leasing service with the Sperry type fissure detector car, operated under the direction of the engineer of tests, is now in its eleventh year.

The demand for service is so urgent that commitments are generally made six months to a year in advance of actual testing. Unfortunately, we have insufficient equipment to meet all demands.

Appendix F

(4) Cause and Prevention of Rail Battering and Methods of Reconditioning Rail Ends, Fastenings and Frogs in Track

F. M. Graham (chairman, subcommittee), W. C. Barnes, L. H. Bond, C. B. Bronson, H. A. Cassil, E. E. Chapman, H. R. Clarke, E. J. Cullen, Robert Faries, Robert H. Ford, B. Herman, W. H. Kirkbride, G. M. Magee, Ray McBrian, Wm. Michel, C. E. Morgan, John V. Neubert, J. C. Patterson, J. C. Ryan, R. T. Scholes, G. R. Smiley, A. N. Talbot, J. C. Wallace, Barton Wheelwright.

Subcommittee 4 is continuing to co-operate with the Rails Investigation of the University of Illinois in studying the prevention of end batter of rails by suitable heat treatment.

During the past year a field test has been initiated to determine the effect of heat treating of rail ends in reducing or preventing rail end batter. This test is located on the Chesapeake & Ohio Railway north of Carey, Ohio, where there is a very heavy tonnage movement at moderate speeds and where new 131-lb. R.E. rail was laid at the time the test was started.

The test comprises 900 joints, 100 of which have the rail ends hardened by each of four different mill methods, 100 joints have the ends hardened by each of four different field methods, and 100 joints were left without end hardening for comparative purposes.

Initial profile measurements of the joints and Brinell hardness values were taken by the Rails Investigation and subsequent similar measurements will be made periodically. It is hoped to learn from this test the character of heat treatment to be provided which will withstand the impact of wheels without damage to the rails and at the same time result in the maximum reduction of batter. The subcommittee wishes to express its appreciation to the C. & O. for the privilege of placing this test in its tracks.

Information is being collected with respect to existing methods of reconditioning rail ends by welding, grinding, etc.

This is submitted as a progress report, and it is recommended that the subject be continued.

Appendix G

(5) Economic Value of Different Sizes of Rail

J. M. Farrin (chairman, subcommittee), W. J. Backes, W. C. Barnes, N. J. Boughton, W. J. Burton, W. A. Duff, Robert Faries, F. W. Gardiner, Maro Johnson, C. S. Kirkpatrick, G. M. Magee, John V. Neubert, A. N. Reece, Barton Wheelwright, J. E. Willoughby, Louis Yager.

Efforts have been directed toward obtaining data from the various railroads on relative costs of installation and maintenance of the different sizes of rail, which are essential for the preparation of a report on the subject.

This is submitted as a progress report, and it is recommended that the subject be continued.

Appendix H

(6) Continuous Welding of Rail

Collaborating With Committee 5—Track and Special Committee on Stresses in Railroad Track

J. C. Patterson (chairman, subcommittee), J. B. Akers, W. C. Barnes, W. J. Burton, E. J. Cullen, Robert Faries, J. M. Farrin, P. O. Ferris, Robert H. Ford, G. W. Harris, G. M. Magee, C. E. Morgan, John V. Neubert, E. E. Oviatt, W. H. Penfield, G. A. Phillips, B. H. Prater, A. N. Reece, R. T. Scholes, G. R. Smiley, J. C. Wallace, J. E. Willoughby, W. P. Wiltsee, Louis Yager.

The general plans for the investigation as outlined on page 389, Vol. 39, of the Proceedings for 1938 are being carried out. The First Progress Report of this investigation was presented at the 1939 annual convention and published in Vol. 40, pages 687–713. The work has been continued by further tests made on rails welded by Process E (gas weld with pressure) and on rails welded by a slightly modified Thermit process.

To secure a basis of comparison of the resistance of welded rail joints to repeated stresses with that of joint-bar joints, a series of rolling load tests on rails connected by joint bars is in progress. Details and results of the tests as far as developed will be presented by Professor H. F. Moore, in charge of the Rails Investigation, University of Illinois, Urbana, Ill., in his report.

In collaboration with Committee 5—Track, it is proposed to supplement the laboratory investigation by a continuing record of the performance of welded joints in service. Methods for securing this information are now being formulated by the committees.

This is a progress report and it is recommended that the subject be continued.

Appendix I

(7) Service Tests of Various Types of Joint Bars

Ray McBrian (chairman, subcommittee), J. B. Akers, W. J. Backes, W. C. Barnes, A. F. Blaess, L. H. Bond, H. A. Cassil, H. R. Clarke, W. A. Duff, Robert Faries, P. O. Ferris, F. W. Gardiner, F. M. Graham, F. S. Hewes, C. S. Kirkpatrick, B. R. Kulp, G. M. Magee, Wm. Michel, C. E. Morgan, John V. Neubert, J. C. Patterson, G. A. Phillips, B. H. Prater, A. N. Reece, J. C. Ryan, G. R. Smiley, A. N. Talbot, J. C. Wallace.

As previously reported, the test joints were applied during the early part of June, 1937, on 112-lb rail, between Toluca, Ill., and Ancona, in the westbound track of the Illinois division of the Atchison, Topeka & Santa Fe Railway, and during the latter part of July, 1937, on 131-lb. rail, between Valparaiso, Ind., and Wanatah, in the eastbound track of the Fort Wayne division of the Pennsylvania Railroad. Measurements have been made by the field forces, and Dr. A. N. Talbot, under whose direction they are working, reports as follows:

During the year, observational tests have been made on the test joints of the two railroads. Necessarily, the measurements generally have been made on only a portion of the joints. Bolt tension measurements have been taken on an increased number of joints. On the half-mile stretches of the Pennsylvania, the bolts in about 20 percent of the joints have had tension measured one or more times this year, and on the mile stretches of the Santa Fe, tension in bolts has been obtained for about 13 percent of the joints. In this way, an effort is being made to keep tab on changes in bolt tension with the passage of time and with variations in the maintenance of the track, as well as to find whether there are differences in maintaining bolt tension, due to differences in the type of bar. Surface profile measurements have been made this year on 360 joints on the Pennsylvania and 270 joints on the Santa Fe; as rail wear is still slight, the data will serve as a basis for future measurement of rail wear and batter. A similar number of joints observed has been measured for rail surface ordinate (to detect possible droop of rail) and bar midordinate (both vertical and lateral) for indicating wear and bending of bars. Joints have been measured again for out-to-out distances to points near the top and bottom of the bars at three places along their length to find cocking and to learn when the wear of bars has resulted in their being drawn closer to the rails. The measurement of rail gaps (taken in summer and winter, a quick job) is giving interesting information on variation in longitudinal movements from rail to rail, whether bunching of movement occurs, and what longitudinal temperature stresses are put into the rail through resistance to movement. The various measurements will doubtless be useful in explaining differences in joint conditions as time and traffic have their effect upon the joints.

Experiences with machine wrenching of bolts on the test track of the Pennsylvania indicate difficulties in securing anything approaching uniformity of bolt tension. The discrepancies in tension found with machine wrenching are more troublesome with moderate bolt tensions, and the general tendency in the use of the machine is to apply a very high bolt tension. Also, experiences with very high bolt tension in joints indicate that it is conducive to the development of high stresses in the bars and doubtless also to bar failures of various kinds, particularly the fatigue failures. The deleterious effect of high bolt tension is shown by the rolling load tests and also by the photoelastic tests made by the Denver & Rio Grande Western Railroad.

How high a bolt tension or how low a bolt tension is permissible, and what is the most important source of wear, are questions of importance. These and other questions are so inter-related that their study is of great value. It is believed that the accumulation of definite data on the various elements entering into joint wear and maintenance will permit definite interpretation of the sources of depreciation and failure and offer clues to the relative value of various types of bar in resisting wear and in giving good track surface over a number of years.

The practice of making notes of general observations on the joints is being continued. These cover such items as the appearance of wear of rail at the joint, both as compared with end hardening and rail treatment on the north and the south lines of rail. Various differences have been noted, but as these are not yet conclusive, no definite statement can now be made on such matters. As an example, the batter at the ends of the end-hardened rail is seen to be less in amount and in length than in the non-hardened rail. No detailed examination of the condition of the joint bars has yet been made. Magnaflux inspection is being used in the field to determine if any cracks are present in the bars. Incidentally, the general wear on the head of the rail, well away from the joint, in the last year of service averages about 0.009 in. on the Pennsylvania and about 0.006 in. on the Santa Fe; the amounts of traffic carried are not yet known.

This is submitted as a progress report, and it is recommended that the subject be continued.

Appendix J

(8) Investigate Joint Bar Failures and Give Consideration to the Revision of Design and Specifications

C. B. Bronson (chairman, subcommittee), J. B. Akers, John E. Armstrong, W. J. Backes, W. C. Barnes, N. J. Boughton, E. E. Chapman, H. R. Clarke, W. A. Duff, Robert Faries, F. M. Graham, F. S. Hewes, W. H Kirkbride, B. R. Kulp, G. M. Magee, Ray McBrian, C. E. Morgan, John V. Neubert, W. H. Penfield, Philip Petri, J. C. Ryan, L. H. Scheifele, R. T. Scholes, A. N. Talbot, J. E. Willoughby, W. P. Wiltsee.

Responses to a questionnaire have been received from practically all of the major railroads in the United States and Canada. Relative to the records of the individual railroads: Those reporting in detail show that only a fraction of one percent of the bars—usually less than two tenths of one percent—are developing cracks or failures per year.

Weighing all of the evidence submitted in the replies to the questionnaire, the subcommittee has reached the following general conclusions:

1. Failures are largely in the lighter sections, namely, those in 100-lb. rail or under. Few failures in toeless type bars reported.

2. Failures are almost entirely in the angle type of bar.

3. The failures are either at the top center near the middle of the bar, or start in the sharp angles of the slots. The percentage of these types of failure varies widely from one road to another; some reporting an abnormal number starting in the slots, others at the top center.

4. There is relatively no difference in the rate of failures for one mill compared with another.

5. The number of failures in light section bars of the angle type in light weight rail is increasing, due to age, poor design, and to slot failures. Failures are generally decreasing in the heavier sections.

6. No change in number or rate of failures due to use of power wrenches.

7. Where power wrenches are used, which appears to be quite general, the bolt tensions aimed for range between 10,000 and 20,000 lb.

8. The method of determining what bolt tension to use is either to check with a hand wrench or to use a calibrated spring; no accurate method is in general use.

9. Whether bars are cocked or out of vertical alinement with the rail is known only in a general way. Bars are usually straightened vertically by striking the toe with a spike maul.

10. Where the practice of reforming is followed, cracked bars are weeded out before this operation. The percentage of cracked bars is rather indefinite, but is usually considerable for the lighter sections of rail.

The request for suggested measures for reducing these failures brought out a variety of ideas, among which are the following:

1. Eliminate spike slots, which of course has been done in the toeless designs now universally accepted, for rail sections heavier than 100 lb.
2. Beveling the rail fishing surfaces.
3. Easement on top center of bar.
4. Mill rail ends.
5. Use head-free type.
6. Harden rail ends.
7. Build up worn or badly battered rail ends.
8. Proper design of bars.
9. Improve heat treatment, or use alloy steels.
10. Set bars vertical when installed.
11. Keep bolts tight and the tension uniform.
12. Maintain proper expansion.
13. Keep joint ties well tamped, and maintain proper support.
14. Avoid striking bars.
15. Use 36 or 38-in. bar instead of 24-in. length.
16. Keep ballast clean. Also retard frost heaving.
17. Keep ties properly spaced.
18. Oil joints.
19. Use shims on worn bars.
20. Decarburized surface should be removed.
21. Improve testing and methods of inspection.

Similarly, a variety of facts and theories are indicated as to the cause of failures, among which are the following:

1. Frozen joints.
2. Bulges in rail fishing area at center of joint.
3. Saw burrs.
4. Fatigue cracks in decarburized metal at top or base of bar.
5. Insufficient anchorage.
6. Nicks in head fishing contact.
7. Overstressing above yield point.
8. Wear at top center.
9. Poor maintenance of joints.
10. Breaks sometimes caused by effect of heat in building up rail ends.
11. Battered rail end is an inducing cause.
12. Shallow depth responsible for light section failures.
13. Loose bolts.
14. Swinging ties.
15. Center depression would overcome failures.

It is noted that many of the items in these two lists pertain strictly to the initial installation and maintenance of the joints, and not to the design or specifications, which are the direct assignment of this subcommittee.

On the question of design, it is quite obvious from the replies, that with two or three exceptions the toeless design of bar is rendering satisfactory service from the standpoint of failures. However, these have been in service on most roads too short a time, relatively, for conclusive evidence.

Two roads are quite firm in their belief that an abnormal number of failures have been and are being developed in bars of the toeless design, and are aggressively pursuing studies on their own initiative in an effort to better the situation. However, in spite of this, the subcommittee, based on data currently received, does not find any general necessity for changes in the design of the toeless bars which are now recommended practice of the Association. Neither is it evident that any changes can be recommended in the present standard specifications for joint bars, or offer new specifications for more elaborate methods of heat treatment or for alloy steels.

Research Work and Experimental Studies

Due to the fact that there are many overlapping features in the studies being made on joint bars, this subcommittee has been in close contact and co-operation with the Committee on Stresses in Railroad Track, as well as Subcommittee 7, and has obtained valuable ideas from them in the studies attempted. In addition, both the Burlington and the Denver & Rio Grande Western have been making some independent studies as well as installations of joint bars manufactured under modified conditions of composition and treatment, the details of which touch directly on the assignment regarding design and specifications.

The work of the first mentioned road embraces a laboratory study of joint bars made of steel, having a composition equivalent to that of rail steel and also double treatment, that is, quench and draw-back, to increase the resistance to fatigue. Interesting data on this may be available at some later date. The work of the second road includes not only that outlined above but also some original research studies embracing the photoelastic method which involves the use of bakelite models and polarized light, to determine how stress concentration areas or points may be avoided.

The subcommittee has contacted two manufacturing plants which have co-operated in certain studies and laboratory investigations. One study relates to the decarburization of the surfaces of joint bars. It is a well known fact that this is inherent in rolled steel products of all types. The line of studies pursued was to determine whether the reheating of the sheared bars increased or decreased decarburization compared with the "as rolled" condition. Comparative etchings and photomicrographs have shown that little change occurred. Some of the samples showed a slight reduction in the depth of the decarburization as the result of reheating and subsequent quenching.

A second series is now under way in which quenching is effected by fine sprays of water on the fishing surfaces for varying periods of time to determine whether the depth of the decarburized zone can be decreased. The results of this series of tests are not yet available.

The studies and installations made by the Burlington and the Denver & Rio Grande Western—in which G. M. Magee, research engineer, actively co-operated—covering improvements in the strength and grain refinement of joint bar steel, will be of material aid to the subcommittee in any future revision, or broadening of the specifications.

General

The desirability of relieving the pressure on the top of the bar at the center is being considered by extending the end chamfer of rails to the points of fishing contact—both head and base. The bulging on the under side of the rail head at the ends is also under consideration by the Rail committee, in an effort to determine how this might be reduced or avoided.

From the standpoint of the installation of joint bars there are two practical considerations which merit individual observations by the railroads.

One is the tendency of toeless bars to cock or lean out of alinement. In the days of slot spiking this was under control, because the slot spikes could not be driven unless the bars were in vertical alinement. On toeless bars the method largely used is to strike the toe inward for vertical alinement which is crude and only fairly effective, especially where power wrenches are used which run the nuts on rapidly. Many track men are apparently unaware of the extent to which bars are cocked in application.

The second point is the study of actual bolt tension by means of the extensometer, which can be done easily and accurately at relatively small expense. Roads are urged to follow this line of study as it has an important bearing on the possible failure of joint bars.

Summary of Service Records of Joint Bar Failures

General

Many of the roads reported that they had no data on joint bar failures to submit, or else did not keep accurate records, and some reported that they kept no records at all. Following are summaries of the records submitted by the reporting roads:

A. T. & S. F.—Information Relative to Toeless Bars.

Number of Failures Between December, 1930, and December, 1938, Inclusive

Rail Section	*Estimated No. Bars*	*Number Failures*	*Percent*	*Percent Per Year*
90	204,500	285	0.13	0.016
110	934,500	2294	0.24	0.03
112	656,700	9	0.0014	....
Total	1,795,700	2588	0.14	0.017

Canadian National—100-lb. Section

Average Record for 1931 to 1934 Inclusive

Head Contact—162.9 failures per 100 track miles per year.
Head Free — 8.7 " " " " " " "

C. M. St. P. & P.—Record January 1, 1938, to April 30, 1939.

Rail Section	*Approx. No. Bars*	*Total Failures*	*Annual Failures % of Total*	*Type Failure—% of Total*		
				Top Center	*Through Slots*	*Bolt Hole & Misc.*
85	521,000	297	0.043	43.7	13.5	42.8
90	1,813,000	2251	0.093	67.5	16.1	16.4
100	1,256,000	739	0.045	....	....	....
110–112	218,000	0	....	....	....	....
130–131	156,000	3	0.002	100.0	....	....
Total	3,964,000	3290	0.062	66.6	16.1	17.3

Note A—Failures divided as follows:

In reformed bars	33.6%
In angle bars—not reformed	53.0%
In 100-lb. bars	11.3%
In miscellaneous sections	2.1%

Note B—99.6 percent of failures were in 24-in. length bars.

C. R. I. & P.—Record for Year 1936

	Failures		
Section	*Slotted*	*Unslotted*	*Total*
80–85–90	18,207	3,098	21,305
100	9,978	64	10,042
110–112	2	48	50
Total	28,187	3,210	31,397

Note—610 welded bars included in totals.

D. & R. G. W.—112-lb. R.E. Controlled Bearing (Head Only) and Full Head Contact Magnaflux Inspection

629 bars, or 38% of total inspected were cracked at top center
107 " " 6% " " " " " " center of base

Erie—Record for 1934 to 1939.

Section	*Miles Track*	*No. Failures*
112	310	None
131	261	None
110	1,007	3 or 4 per year
130	424	3 or 4 per year

K. C. S.—Average Failures per Mile per Year.
One for 100 and 127-lb. and five for the 85-lb. sections.

N. Y. C. & St. L.—July, 1938, to April, 1939, inclusive.
181 pairs in the 110-lb. section rolled in 1925 and 1926.
No record for failures in the 90 and 105-lb. sections.

N. Y. Central System—

Failed In	*Section*	*Estimated No. Bars*	*No. Cracked or Broken*	*Percent of Total*
1937	127	2,150,000	505	0.023
1938	127	2,250,000	632	0.028
1937	105	4,450,000	7916	0.18
1938	105	4,400,000	6448	0.15

Note:—Eight failures have developed in the 127-lb. toeless type bar. All others were angle bar type.

All failures in 105-lb. section were angle bar type.

Of the totals shown for 105-lb. section, 2,714 in 1937 record, and 2,280 in the 1938 record were heat treated bars. The balance were either untreated or reformed bars.

This is submitted as a progress report and it is recommended that the subject be continued.

Report of Special Committee on Complete Roadway and Track Structure

JOHN E. ARMSTRONG, *Chairman,*
A. E. BOTTS
JOHN FOLEY
JOHN V. NEUBERT
W. G. ARN
Committee.

To the American Railway Engineering Association:

Your committee respectfully reports on the following subjects:

1. Classification of railways (Appendix A). Complete with recommended conclusions for publication in the Manual.

2. Complete roadway and track structure for various loads and traffic densities (Appendix B). Complete and presented as information, with recommended note for inclusion in the Manual.

THE SPECIAL COMMITTEE ON COMPLETE ROADWAY AND TRACK STRUCTURE,
JOHN E. ARMSTRONG, *Chairman.*

Appendix A

(1) Classification of Railways

This committee submitted to last year's convention of the Association a tentative classification of railway main tracks, which appears on page 628 of Volume 40 of the Proceedings. It recommended that this classification be accepted as a progress report for discussion, criticisms and suggestions.

The discussion, criticisms and suggestions received indicate that, in general, the tentative classification was acceptable, but that it did not make entirely clear just what was intended. The ambiguous matter has been clarified.

With these revisions there is now submitted the following:—

TRAFFIC CLASSIFICATION OF RAILWAY MAIN TRACKS

Class A—A railway main track—

1. Which carries a total of 12,500,000 tons or more per annum, such tonnage to be determined in 2,000-lb. tons, and to include the total weight of all cars, contents and locomotives handled over that track, or—
2. Over which freight trains are normally operated at average speeds of 40 miles or more per hour between stops, or—
3. Over which passenger trains are normally operated at average speeds of 60 miles or more per hour between stops.

Class B—A railway main track—

1. Which carries a total of more than 5,000,000 but less than 12,500,000 tons per annum, such tonnage to be determined in 2,000-lb. tons, and to include the total weight of all cars, contents and locomotives handled over that track, or—
2. Over which freight trains are normally operated at average speeds of more than 25 but less than 40 miles per hour between stops, or—
3. Over which passenger trains are normally operated at average speeds of more than 40 but less than 60 miles per hour between stops.

Bulletin 416, February, 1940.

Class C—A railway main track—

1. Which carries a total of not more than 5,000,000 tons per annum, such tonnage to be determined in 2,000-lb. tons, and to include the total weight of all cars, contents and locomotives handled over that track, or—
2. Over which freight trains are normally operated at average speeds of not more than 25 miles per hour between stops, or—
3. Over which passenger trains are normally operated at average speeds of not more than 40 miles per hour between stops.

Note.—A railway main track is Class A by traffic if it conforms to any one or more of the three requirements for Class A main track; is Class B by traffic if it conforms to any one or more of the three requirements of Class B main track, but to no one of the requirements of Class A main track; and is Class C by traffic if it conforms to no one of the requirements of either Class A or Class B main track.

The committee recommends that the foregoing Classification of Railway Main Tracks and the note pertaining thereto be adopted for inclusion in the Manual.

Appendix B

(2) Complete Roadway and Track Structure for Various Loads and Traffic Densities

This committee submitted to last year's convention of the Association a tentative schedule of classes of complete roadway and track structure under AREA Recommended Practice, which appears on pages 630 to 633 of Volume 40 of the Proceedings, and recommended that this schedule be accepted as a progress report for discussion, criticisms and suggestions. All discussion, criticisms and suggestions received have been considered.

In conjunction and conformity with the Traffic Classification of Railway Main Tracks in Appendix A of this report, there is submitted herewith a Schedule of Classes of Complete Roadway and Track Structure under AREA Recommended Practice as of 1939.

The three classes of complete roadway and track structure must not be regarded as definitely fixed and mutually exclusive as to details. For example, although 131-lb. R.E. rail is indicated for only Class A roadway and track structure it is quite possible that under some conditions it may be economical for Class B roadway and track structure. Similarly, 90-lb. R.A.-A. rail under some conditions may be economical for Class A as well as for Class B and Class C roadway and track structure.

More unfavorable conditions than average, such as steep gradients, sharp curvature, tunnels and others which are not referred to in the Traffic Classification of Railway Main Tracks, may make economical, in whole or in part, a higher class of roadway and track structure than that indicated by annual tonnage and train speeds alone. Similarly, more favorable conditions than average may make economical, in whole or in part, a lower class of roadway and track structure than that indicated by annual tonnage and train speeds alone. Such unfavorable and favorable conditions, however, should be treated as special cases, and the track and roadway structure should be provided according to the specific requirements.

Having in mind the many variations in local conditions other than annual tonnage and train speeds, it is suggested that the several Schedules of Classes of Complete Roadway and Track Structure should be regarded either as applicable to average conditions, or as indicative rather than as absolute in so far as their respective details are concerned.

When materials other than those noted are used they should be at least the equivalent of those noted, except that in the lower ranges of Class C main track the equivalent of 90-lb. R.A.–A. track is not required and available materials may be used in accordance with actual requirements.

Recommendation

That, if the recommendation in Appendix A is approved, this report be accepted as information, and that immediately after the Traffic Classification of Railway Main Tracks as printed in the Manual, there be printed a reference to it as follows:

SCHEDULE OF CLASSES OF COMPLETE ROADWAY AND TRACK STRUCTURE—1939

For this Schedule, which is based upon 1939 Recommended Practice and the foregoing Traffic Classification of Railway Main Tracks, and for the report citing the limitations of this Schedule, see pages 642 to 645 of Volume 41 of the Proceedings.

SCHEDULE OF CLASSES OF COMPLETE ROADWAY AND TRACK STRUCTURE UNDER AREA RECOMMENDED PRACTICE

1939

ITEM	*CLASS "A"*	*CLASS "B"*	*CLASS "C"*	*MANUAL REFERENCE*	
				Item	*Page*
ROADWAY					
General	Specifications	Specifications	Specifications	1–401	1–27
Width at Subgrade	As required	As required	As required	1–402–A	1–34
Slopes	As required	As required	As required	1–402–B	1–35
Slope Protection	As required	As required	As required	1–602	1–65
Surface Drainage	As required	As required	As required	1–503	1–43
Sub-surface Drainage	As required	As required	As required	1–504	1–46
BALLAST					
Sub-ballast					
Material	As available	As available	As available		45 & 2–15
Ballast or Top Ballast					
Material					
Stone	Specifications	Specifications	Specifications		2–1 & 2–15
Slag	Specifications	Specifications	Specifications		2–13 & 2–15
Prepared Gravel					
More than 20% crushed	Specifications	Specifications	Specifications		2–7 & 2–15
20% and less crushed	Specifications	Specifications	Specifications		2–7 & 2–15
Pit Run Gravel	See Note "A"	Specifications	Specifications		2–11 & 2–15
Cinders	See Note "A"	See Note "A"	As available		2–15
Ballast Section					
With Sub-ballast	1(a) to 1(e) incl.	1(e) to 1(i) incl.	1(i) to 1(m) incl.		2–17
	3(a) to 3(d) incl.	3(d) to 3(i) incl.	3(i) to 3(p) incl.		2–18
Without Sub-ballast	2(a) to 2(h) incl.	2(h) to 2(l) incl	2(l) to 2(p) incl.		2–17
	4(a)	4(a) to 4(e) incl.	4(e) to 4(m) incl.		2–18
CROSS TIES					
General	Specifications	Specifications	Specifications		3–1
Kind	Best available	Best available	Best available	3–101	3–1
Size	5 or 4	5 or 4	5, 4 or 3	3–301	3–2 & 3–15
Length	9 ft., 8 ft. 6 in., or 8 ft.	8 ft. 6 in., or 8 ft.	8 ft.	3–301	3–2 & 3–15
Number per 39 ft. rail	25 to 23	25 to 23	23 or less		3–15
Untreated	Class "U"	Class "U"	Class "U"	3–605	3–4
Treated	Class "T"	Class "T"	Class "T"	3–605	3–4
Machined as required	Specifications	Specifications	Specifications		3–9 & 3–20
Treatment	Specifications	Specifications	Specifications		17–1 & 17–3
Process					
Lowry	Specifications	Specifications	Specifications		17–3 & 17–6
Rueping	Specifications	Specifications	Specifications		17–3 & 17–7
Preservative					
Creosote	Specifications	Specifications	Specifications		17–13
Creosote-Coal Tar Solution	Specifications	Specifications	Specifications		17–14

SCHEDULE OF CLASSES OF COMPLETE ROADWAY AND TRACK STRUCTURE UNDER AREA RECOMMENDED PRACTICE—Continued

1939

ITEM	*CLASS "A"*	*CLASS "B"*	*CLASS "C"*	*MANUAL REFERENCE*	
				Item	*Page*
TIE PLATES					
Material					
Wrought Iron	Specifications	Specifications	Specifications		5-11
Soft Steel	Specifications	Specifications	Specifications		5-1
Medium Steel	Specifications	Specifications	Specifications		5-1
High Carbon Steel	Specifications	Specifications	Specifications		See Note "B"
Design					
For Wrought Iron					
With 131-lb. R. E. rail	See Note "B"	See Note "A"	See Note "A"		See Note "B"
With 112-lb. R. E. rail	See Note "B"	See Note "B"	See Note "A"		See Note "B"
With 100-lb. R. E. rail	See Note "B"	See Note "B"	See Note "B"		See Note "B"
With 90-lb. R.A.-A. rail	See Note "A"	See Note "B"	See Note "B"		See Note "B"
For Soft Steel					
With 131-lb. R. E. rail	See Note "B"	See Note "A"	See Note "A"		See Note "B"
With 112-lb. R. E. rail	See Note "B"	See Note "B"	See Note "A"		See Note "B"
With 100-lb. R. E. rail	See Note "B"	See Note "B"	See Note "B"		See Note "B"
With 90-lb. R.A.-A. rail	See Note "A"	See Note "B"	See Note "B"		See Note "B"
For Medium Steel					
With 131-lb. R. E. rail	Plan No. 6—See Note "C"	See Note "A"	See Note "A"		5-5 & 5-10
	Plan No. 5—See Note "D"	See Note "A"	See Note "A"		5-5 & 5-9
	Plan No. 3—See Note "D"	See Note "A"	See Note "A"		5-5 & 5-7
With 112-lb. R. E. rail	Plan No. 4—See Note "D"	Plan No. 4—See Note "D"	See Note "A"		5-5 & 5-8
	Plan No. 2—See Note "D"	Plan No. 2—See Note "D"	See Note "A"		5-5 & 5-6
	See Note "A"	Plan No. 1C—See Note "E"	See Note "A"		5-5 & 5-5.3
With 100-lb. R. E. rail	Plan No. 2—See Note "D"	Plan No. 2—See Note "D"	See Note "A"		5-5 & 5-6
	See Note "A"	Plan No. 1C—See Note "E"	Plan No. 1C—See Note "E"		5-5 & 5-5.3
With 90-lb. R.A.-A. rail	See Note "A"	Plan No. 1B—See Note "E"	Plan No. 1B—See Note "E"		5-5 & 5-5.2
	See Note "A"	Plan No. 1A—See Note "E"	Plan No. 1A—See Note "E"		5-5 & 5-5.1
For High Carbon Steel					
With 131-lb. R. E. rail	See Note "B"	See Note "A"	See Note "A"		See Note "B"
With 112-lb. R. E. rail	See Note "B"	See Note "B"	See Note "A"		See Note "B"
With 100-lb. R. E. rail	See Note "B"	See Note "B"	See Note "B"		See Note "B"
With 90-lb. R.A.-A. rail	See Note "A"	See Note "B"	See Note "B"		See Note "B"
HOLD DOWN SPIKES					
Type					
Screw	Specifications	Specifications	See Note "A"		See Note "B"
Cut	Specifications	Specifications	See Note "A"		5-15
Design					
Screw	See Note "B"	See Note "B"	See Note "A"		See Note "B"
Cut	6 in. x 5/8 in.	6 in. x 5/8 in.	See Note "A"		5-17
Number per Tie Plate					
Screw	As required	As required	See Note "A"		See Note "B"
Cut	As required	As required	See Note "A"		See Note "B"

SCHEDULE OF CLASSES OF COMPLETE ROADWAY AND TRACK STRUCTURE UNDER AREA RECOMMENDED PRACTICE—Continued

1939

ITEM	*CLASS "A"*	*CLASS "B"*	*CLASS "C"*	*MANUAL REFERENCE*	
				Item	*Page*
RAIL					
General	Specifications	Specifications	Specifications		4-1
Section					
131-lb. R. E.	Figure 404	See Note "A"	See Note "A"		4-11
112-lb. R. E.	Figure 403	Figure 403	See Note "A"		4-10
100-lb. R. E.	Figure 402	Figure 402	Figure 402		4-9
90-lb. R. A. -A.	See Note "A"	Figure 401	Figure 401		4-8
Drilling					
131-lb- R. E.	4 or 6 hole	See Note "A"	See Note "A"		4-12 & 4-28
112-lb. R. E.	4 or 6 hole	4 or 6 hole	See Note "A"		4-12 & 4-27
100-lb. R. E.	4 or 6 hole	4 or 6 hole	4 or 6 hole		4-12 & 4-26
90-lb. R. A. -A.	See Note "A"	4 or 6 hole	4 or 6 hole		4-12 & 4-25
Length	39 ft.	39 ft.	39 ft.	4-402	4-3
Classification	No. 1	No. 1	No. 1	4-304	4-3
JOINT BARS					
Material					
High Carbon Steel	Specifications	Specifications	Specifications		4-17
Quenched Carbon Steel	Specifications	Specifications	Specifications		4-21
Section					
For 131-lb. R. E. rail	Plan	See Note "A"	See Note "A"		4-28
For 112-lb. R. E. rail	Plan	Plan	See Note "A"		4-27
For 100-lb. R. E. rail	Plan	Plan	Plan		4-26
For 90-lb. R. A. -A. rail	See Note "A"	Plan	Plan		4-25
Length and Punching					
For 131-lb. R. E. rail	36 in. with 6 holes	See Note "A"	See Note "A"		4-28
	24 in. with 4 holes	See Note "A"	See Note "A"		4-28
For 112-lb. R. E. rail	36 in. with 6 holes	36 in. with 6 holes	See Note "A"		4-27
	24 in. with 4 holes	24 in. with 4 holes	See Note "A"		4-27
For 100-lb. R. E. rail	36 in. with 6 holes	36 in. with 6 holes	36 in. with 6 holes		4-26
	24 in. with 4 holes	24 in. with 4 holes	24 in. with 4 holes		4-26
For 90-lb. R. A. -A. rail	See Note "A"	36 in. with 6 holes	36 in. with 6 holes		4-25
	See Note "A"	24 in. with 4 holes	24 in. with 4 holes		4-25
TRACK BOLTS AND NUTS					
General	Specifications	Specifications	Specifications		4-29
Design					
For 131-lb. R. E. rail	1 in. x 6¼ in.	See Note "A"	See Note "A"		4-28 & 4-33
For 112-lb. R. E. rail	1 in. x 6 in.	1 in. x 6 in.	See Note "A"		4-27 & 4-33
For 100-lb. R. E. rail	1 in. x 5½ in.	1 in. x 5½ in.	1 in. x 5½ in.		4-26 & 4-33
For 90-lb. R. A. -A. rail	See Note "A"	1 in. x 5¼ in.	1 in. x 5¼ in.		4-25 & 4-33

SCHEDULE OF CLASSES OF COMPLETE ROADWAY AND TRACK STRUCTURE UNDER AREA RECOMMENDED PRACTICE—Continued

1939

ITEM	*CLASS "A"*	*CLASS "B"*	*CLASS "C"*	*MANUAL REFERENCE*	
				Item	*Page*
SPRING WASHERS—See Note "F"					
General	Specifications	Specifications	Specifications		4-37
TRACK SPIKES					
General	Specifications	Specifications	Specifications		5-15
Design					
6 in. x $\frac{5}{8}$ in.	Plan	Plan	See Note "A"		5-17
$5\frac{1}{2}$ in. x $\frac{9}{16}$ in.	See Note "A"	Plan	Plan		5-17
Number per tie plate	As required	As required	As required		See Note "B"
ANTI-CREEPERS					
General	Specifications	Specifications	Specifications		See Note "B"
Number per 39 ft. rail	As required	As required	As required		5-18

NOTES:
"A"—This item will not ordinarily be used in this class of Track.
"B"—Recommended Practice not yet determined
"C"—With double shoulders and screw hold down spikes.
"D"—With or without double shoulders and with or without screw or cut hold down spikes as required.
"E"—With or without double shoulders and without screw or cut hold down spikes as required.
"F"—Spring washers to be used only when Recessed Nuts are not used.

Report of Committee 3—Ties

JOHN FOLEY, *Chairman,*
R. S. BELCHER
W. C. BOLIN
W. H. BRAMELD
H. F. BROWN
W. J. BURTON
R. E. BUTLER
F. G. CAMPBELL

S. B. CLEMENT
R. L. COOK
C. F. FORD
W. E. GARDNER
B. D. HOWE
W. S. KING*
C. S. KIRKPATRICK
D. O. LYLE

H. R. DUNCAN, *Vice-Chairman,*
A. F. MAISCHAIDER
W. D. SIMPSON
SVERRE THORVALDSON
C. D. TURLEY
A. W. WHITE
Committee.

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* Died, April 14, 1939.

To the American Railway Engineering Association:

Your committee respectfully reports on the following subjects:

1. Revision of Manual. No recommendations.
2. Extent of adherence to specifications (Appendix A). Presented as information.
3. Substitutes for wood ties (Appendix B). Presented as information.
4. Tie renewal averages and costs per maintained mile, securing data from reports to I.C.C. (Appendix C). Presented as information.
5. Proper seasoning of oak ties with special reference to those grown in southern lowlands, collaborating with Committee 17—Wood Preservation (Appendix D). Final statement recommending that the subject be discontinued.
6. Investigate and report on the dimensions of ties, and bring up to date the information presented in the 1924 and 1932 Proceedings (Appendix E). Presented as information.
7. Cause and control of splitting in railroad ties (Appendix F). Presented as information.

THE COMMITTEE ON TIES,
JOHN FOLEY, *Chairman.*

Appendix A

(2) Extent of Adherence to Specifications

H. R. Duncan (chairman, subcommittee), R. S. Belcher, W. C. Bolin, W. H. Brameld, H. F. Brown, W. J. Burton, F. G. Campbell, R. L. Cook, C. F. Ford, W. E. Gardner, B. D. Howe, W. D. Simpson, Sverre Thorvaldson, A. W. White.

The seasoning and creosoted stocks of nine railroads were examined during 1939 by the committee as a whole, six in North Atlantic and three in South Atlantic states. A total of 1,325,000 ties was observed.

With three exceptions, all of these railroads obtained their ties adjacent to their lines. One railroad of the Great Lakes region imported pine ties from the Southern region, and two railroads in the Central region imported oak ties from Tidewater, Va.

The ties of three eastern railroads observed in two yards were in a condition that left much to be desired. Also, the ties of these railroads would have been much better if all decayed ties had been rejected and if no tolerances of substandard dimensions had been allowed. The ties of all the eastern railroads were in general poorly manufactured.

The southern railroad whose ties were farthest from standard in all respects, requires its supervisors to assume responsibility for the inspection of the ties purchased,

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Bulletin 416, February, 1940.

and the results obtained are typical of those of other roads that have added this task to the regular duties of the track supervisory officers. The undersize, unsound and poorly manufactured ties observed in the stock of this railroad stand out in marked contrast with those being seasoned for two other southern roads whose controlled inspection forces produce better and far more uniform results. Two of the three southern seasoning yards were in satisfactory condition. The vegetation in the other was so rank as to constitute an extreme fire hazard.

The general excellence of the ties accepted by five of the nine railroads whose stocks were observed, confirms the conviction of the committee that carelessness on the part of a railroad is the reason for any substandard ties in its stock. Well made full size ties, free of decay, can be had by any railroad that insists on compliance with AREA specifications.

This report is submitted as information.

Appendix B

(3) Substitutes for Wood Ties

A. F. Maischaider (chairman, subcommittee), R. E. Butler, S. B. Clement.

An alphabetical compilation of ties subjected to trial in substitution for wood ties is given on the folded insert sheets for the information of those interested in the subject.

This report is submitted as information.

Appendix C

(4) Tie Renewal Averages and Costs per Maintained Mile

Securing Data from Reports to I. C. C.

John Foley (chairman, subcommittee), W. J. Burton, R. E. Butler, H. R. Duncan, A. F. Maischaider, C. D. Turley.

The statistics of tie renewals appearing on the folded inserts (Tables A and B for 1938, and Table C for the past five years and the average of them) comprise the data reported to the Interstate Commerce Commission by railroads of the United States and to this Association by Canadian roads. They were given advance publication in Bulletin 411, June–July, 1939.

Comparisons between railroads are practicable only when allowance is made for variations in practice which would influence the costs in Columns 3 and 5 of Table A, and Column 6 of Table B. Differences in the prices at which ties are charged out are due not only to the factors listed on page 309 of the 1929 Proceedings, but are affected also by whether or not these costs include expenses for adzing, boring, incising or ironing any or all ties, for freight on preservative and ties to the treating plant, for inspection, etc.

This report is submitted as information.

Sheet 1 of 2

TESTS OF SUBSTITUTE TIES IN THE UNITED STATES

TESTS OF SUBSTITUTE TIES IN THE UNITED STATES

Name of Tie	Kind	Railroad	Location	Installed Number	Installed Year	Number Removed	Year Last Tie Removed	Maximum Life Secured	Kind of Ballast	Remarks by User
Affleck	Concrete	Penna.	Emsworth	100	1904	All	1905	7 Months	Stone	-
"	"	N. Y. C.	Chesterton, Ind.	15	1904	All	-	No Record	Cinders	Placed in Passing Siding
Alfred	Concretd	Pere Marquette	Various	233	1904	230	-	-	-	No record of service available
"	"	Pere Marquette	Saginaw	14	1902	11	-	-	-	Three ties still in track
American	Concrete	Norf.& W.Ry.	Portsmouth, Va.	139	1913-23	All	1932	1[illegible] Years	-	-
Applegate	See "Clark"									
Atwood	Conc.& Steel	P.& L.E.	McKees Rocks, Pa.	5	1908	All	1923	15 years	Slag	-
Bailey	Concrete	Can.Nat'l	Keewabowie Div.	20	1929	-	-	-	-	Ties still in track
Baird	Steel	A.T.& S.F.	Newton, Kansas	7	1910	All	1925	15 years	Rock	Not satisfactory
Bates	Concrete	E.J.& E.	Whiting	62	1912	All	1936	24 years	Cr.Stone	
Bethlehem	See "Keystone"									
"	Metal Tie									
Bidwell	Concrete	Alton	Kansas City, Mo.	-	1897	-	-	-	-	No record of service available
Boughton	Cast Steel	B.& O.	Akron, O.	17	1904	All	1916	12 years	Cinder	Would not stand shock - easily broken
Bowman		Penna.	Emsworth	5	1905	All	-	1 day	-	-
Bronson	Steel	A.T.& S.F.	Chillicothe	11	1914	All	1924	10 years	-	Would not hold line and surface- corroded
Brown	Concrete	B.& L.E.	Oakmont, Pa.	1,577	1930	All	1936	6 years	Slag	Spalled and shattered underrail
"	"	Penna.	Aspinwall	100	1925	All	1936	11 years	Cinder	-
"	"	"	Bellwood	3,006	1927	All	1936	9 years	Stone	-
"	"	"	Hays	410	1925	44	-	-	Stone	366 still in track
"	"	"	Monongahela	2,516	1927	234	-	-	Cinder	2282 " " "
"	"	"	Tunnelton	2,385	1924	54	-	-	Cinder	2331 " " "
"	"	"	Wilkinsburg	1,861	1928	1	-	-	Stone	1860 " " "
"	"	"	Pitcairn	3,336	1928	249	-	-	Cinder	3087 " " "
"	"	"	Derry	1,878	1927	34	-	-	Cinder	1844 " " "
"	"	"	Connritt Jct.	2,843	1927	1,377	-	-	Stone	1466 " " "
"	"	"	Octorara	1,993	1927	161	-	-	Slag	1832 " " "
"	"	"	Conowingo	1,986	1927	114	-	--	Cinder	1872 " " "
"	"	"	Haines	970	1927	126	-	-	Slag	844 " " "
"	"	"	MP 31, A&S Br.	515	1927	78	-	-	Cinder	437 " " "
"	"	"	Highspire	1,486	1927	91	-	-	Cinder	1395 " " "
Brukner	Concrete	Penna.	Scully Yard	18	1909	All	1911	2 years	Cinder	Installed in yard track
"	"	"	Scully Yard	20	1911	All	1912	1 year	Cinder	" " " "
"	"	P.& L.E.	McKees Rocks	20	1911	All	1915	4 years	Slag	-
Brunson	-	Chicago Jct.	Chicago	19	1904	All	1904	Few Months	-	Evidently not a success
Buhrer	Steel Rail and Concrete	Ann Arbor (Wabash) -		77	1908	All	-	-	-	Not allowed to remain in track very long
"	"		Milwaukee	15	1902	All	1914	12 years	-	-
"	"	L.& M.	Danbury, O.	550	-	All	-	-	-	No record of service
"	"	LE&W (NYC&StL)	Tipton, Ind.	24	1903	All	1924	21 years	-	-
"	"	N.Y.C.	Sandusky, O.	1,500	1903-4	1,475	-	-	Cinders	25 remaining in fair condition
"	"	N.Y.C.	Sandusky, O.	1,650	1905-6	All	1908	2 years	Gravel	Difficulty with clips and insulation
"	"	Penna.	Emsworth	600	1903	All	1906	3 years	Stone	-
Carnegie	Unsymmetrical "I"Beam	A.T.& S.F.	Chanute, Kansas	55	1913	All	1919	6 years	Mixed	Unsatisfactory - broke badly
"	"	A.T.& S.F.	Newton, Kansas	46	1913	-	1917	4 years	Mixed	Corroded badly - not satisfactory
"	"	B.& O.	Mariottsville	2,690	1906	All	1912	6 years	Stone	Would not stand shock - bolts failed
"	"	B.& L.E.	Various	1,170,037	1907-16	1,057,784	-	16 years	Slag	112,255 in main and side tracks 1-1-39
"	"	B.& M.	Boston	Set Switch	1906	-	-	7 years	-	-
"	"	B.R.& P.	(Golden, N.Y.	3,000)	1906	All	1918	1[illegible] years	-	-
"	"	B.R.& P.	(Ridgeway, Pa.							
"	"	C.C.C.& St.L.	Greensburg, Ind.	3,000	1908	All	1926	18 years	Gravel	-
"	"	D.M.& I.R.	Various	2,000	1905	1,555	To date	-	Gravel	455 still in track
"	"	D.M.& I.R.	Duluth, Proctor, Sax	22,380	1908	5,991	To date	-	Rock	16,389 still in track
"	"	E.J.& E.	Various Cross	- 20,576	1909-17	19,053	To date	-	Slag	1,523 steel cross ties still in track
"	"	"	" Switch	- 43,892	1909-17	43,212	To date	-	Gravel	680 " switch " " " "
"	"	Erie	Bergen Yard	Set Switch	1909	All	1916	7 years	-	-
"	"	"	Cleveland	" "	1909	All	1914	5 years	-	-
"	"	"	Jamestown	384	1909	All	1919	10 years	-	-
"	"	L.C.& M.	-	48	1906	-	-	-	-	No record
"	"	Lake Terminal	Lorain, O.	81,273	1908-23	58,604	1938	-	Slag	Heavy industrial interchange traffic
"	"	Long Island	Hicksville	30	1909	All	1929	20 years	-	Last 6 removed 1929 - Unsatisfactory
"	"	Lehigh Valley	-	-	1906	-	-	-	-	No record of service available
"	"	N.& S.S.	Cleveland Switch	*257,925 LF	1907-18	*256,915 LF	To date	-	Slag &	Collapse of web directly under rail bear-
"	"	"	" Cross	*88,052 LF	1907-16	*53,451 LF	To date	-	Cinders	" " " " " ing
"	"	Nickel Plate	Cleveland	60	1906	- -	-	-	-	No record available
"	"	N.Y.C.	Castleton	3,000	1904	All	1906	2 years	Stone	Transferred to adjoining freight track 1906
"	"	P.& L.E.	McKees Rocks	1,000	1907	All	1917	8 years	Slag	-
"	"	Penna.	Atglen, Pa.	3,000	1913	All	1918	5 years	Cinder	-
"	"	Pennsylvania	Pitcairn Yard	#8 Turnout	1912	-	1918	6 years	-	-
"	"	P.S.& N.	Byrnedale Br.	795	1907	All	1927	20 years	Gravel	Removed because of web crushing
"	"	P.& L.E.	Pittsburgh	6	1908	All	1918	10 years	Slag	-
"	"	Union RR	Pittsburgh	5,000	1908	All	-	-	-	No record
Chamberlain	-	TRRAofStL	St.Louis	10	1920	All	1926	6 years	-	-
Champion	Steel & Conc.	Penna.	Lenover, Pa.	995	1920	All	1925	5 years	Cinder	-
"	"	Penna.	Emsworth, Pa.	203	1913	All	1917	4 years	Stone	-
Chenoweth	Concrete	Penna.	Scully Yard	101	1906	All	1913	7 years	Cinder	-
Chester	Steel & Conc.	H.& B.T.M.	Huntingdon, Pa.	-	1899	All	1920	20 years	-	Not satisfactory
Clark (Applegate)	Steel and Wood	S.L.& S.F.	Springfield, Mo.	125	1914	35	1933	19 years	Cinder	Metal parts badly corroded
Coffman	-	N.& W.	Bluefield, W.Va.	-	1909	-	-	-	-	No record of service available
Dalton	Concrete	D.& H.	Various	149,317	1927-38	-	-	-	-	43 ties insp.1937 in good condition
Daniel	"	N.Y.L.E.& W.	Youngstown, O.	17	1891	-	-	-	-	No record of service available
Duke	"	A.& W.P.	Louise, Ga.	10	1927	2	1935	-	Stone	8 ties still in track 1939
Golder	Steel	N.Y.C.	Cleveland	6	1894	-	-	-	Gravel	No record of service - probably removed
Goodlett	Concrete	Sac.Northern	Pleasant Hill, Cal.	150	1917	All	1917	Few months	Gravel	-
"	"	Sou.Pacific	Oakland, Cal.	14	1914	All	1915	1 year	Gravel	-
"	"	"	Oakland, Cal.	27	1917	All	1928	11 years	Gravel	-
Grant	Steel	St.L.& S.F.	Sapulpa, Okla.	4	1914	All	1925	11 years	Chatts	-
Hammond	-	Southern	-	2	1891	-	-	-	-	No record of service available
Hamme	Concrete	A.T.& S.F.	Rivera, Cal.	8	1912	All	1920	8 years	Gravel	Would not hold line or surface
Hanson	Steel	Penna.	Emsworth	500	1905	All	1918	13 years	Stone	Difficulty with insulation
Hardman	Steel and Wood	B.& O.	W. Baltimore	29	1917	All	1919	2 years	Stone	Wood splintered and decayed rapidly
"	"	D.L.& W.	E. Dover, N.J.	30	1918	All	1924	6 years	-	-
Harrell	Concrete	P.F.W.& C.	Chicago-UnionSta.	30	1899	All	1901	2 years	-	-
"	"	Penna.	Hagewish	10	1901	-	-	-	-	Industry track - no record of service
Hartford	"Katte Type" Conc. Also called "Schoen"	N.Y.C.	New York 110th St.	1,350	1896	All	1899	3 years	-	Too light- broke under rail - Could not hold line or surface
"	"	N.Y.C.	Garrison, N.Y.	1,200	1892	All	1900	8 years	-	do
Hatch	Concrete	D.& I.R.	Two Harbors, Minn.	11	1923	All	1937	13 years	Gravel	*
Hickey	Rail in Conc.	M.C.	St.Thomas, Ont.	40	1904	All	1908	4 years	Stone	Rail bearings not perfected
Hicks	-	D.L.& W.	Hoboken	6	1891	-	-	-	-	No record of service available
Iekes	Concrete	A.T.& S.F.	Chanute, Kan.	7	1915	All	1919	4 years	Gravel	Worthless
"	"	Kan.City Sou.	Kansas City	27	1921	All	1932	11 years	-	Now in side track

* L.F.- Lineal Feet - Carnegie Ties on N.& S.S.

Sheet 2 of 2

TESTS OF SUBSTITUTE TIES IN THE UNITED STATES

Installed	Number	Year Last Tie	Maximum Life	Kind of Ballast	Remarks by User

TESTS OF SUBSTITUTE TIES IN THE UNITED STATES

Name of Tie	Kind	Railroad	Location	Installed Number	Installed Year	Number Removed	Year Last Tie Removed	Maximum Life Secured	Kind of Ballast	Remarks by User
Indestructible	Steel	D.T.& I.	Detroit	499	1928	60	-	-	Slag	Found unsatisfactory
"	"	Sou.Pacific	Houston, Tex.	100	1926	All	1928	2 years	-	Not economical for light and not satisfactory for heavy service
"	"	"	EaglePass, Tex.	23	1916	All	-	-		
International	Concrete	B. & M.	Somerville, Mass.	Few	1885	-	-	-	-	No record on Boston & Maine
"	"	Long Island	"	20	1887	-	-	-	-	No record of life
"	"	Maine Central	Portland, Me.	Few	1886	-	--	-	-	No record of life available
"	"	P.& L.E.	Glassport	32	1911-12	All	1915	4 years	Slag	-
Inverted Trough	Steel	B.& L.E.	Osgood, Pa.	2,000	1901	All	1915	14 years	Slag	-
" "	"	Penna.	E.Philadelphia	500	1888	-	—	-	-	No record of service available
Israel	Conc. & Metal Plate	C.C.C.& St.L.	Paris, Ill.	20	1909	All	1912	3 years	Gravel	-
Jennings	Combination	B.& O.	Baltimore	5	1906	All	1908	2 years	Stone	-
Katte	See "Hartford"									
Keefer	Concrete	Penna.	Scully Yard	44	1905	All	1906	1 year	Cinder	Not adapted for Gen'l use acct.not insulated
Keystone (Bethlehem)	Metal Tie	Reading Co.	Reading, Pa.	20	1930	-	-	-	Stone	Still in track
"	"	L.O.& Mt.M.	Port Huron, N.Y.	256	1930-6	-	-	-	-	Still in track
Kimball	Steel-Conc.-Wood	Alton	Lockport, Ill.	75	1905	All	1913	8 years	Stone	Removed account failure of concrete
"	"	D.M.& N.	Virginia, Minn.	30	1914	-	-	—	-	Still in track
"	"	Nickel Plate	Cleveland	6	1905	All	1912	7 years	-	-
"	"	"	"	8	1903	All	1910	7 years	-	Removed account grade elimination
"	"	Penna.	Scully Yard	1	1911	1	1917	6 years	Cinder	-
"	"	Pere Marquette	Walkerville, Ont.	2	1905	All	-	-	-	Removed before 1920
"	"	"	Saginaw	2	1900	All	-	-	-	No record of service
"	"	"	Port Huron	1	1900	All	-	-	-	No record of service
"	"	"	Pelton, Ont.	2	1903	All	-	-	-	No record - Removed before 1920
"	"	"	Bay City, Mich.	2,060	1902	-	-	-	-	In public street track abandoned
King	Concrete & Steel	Long Island	Jamaica Station	33	1924	All	1930	6 years	Stone	Installed along passenger platform
"	"	Long Island	Long Island City	34	1912	All	1928	14 years	-	-
Krupp	-	D.& R.G.W.	Denver	Few	1887	All	-	-	-	Taken out after short time
LaGuna (Weber)	Concrete	A.T.& S.F.	Vegela, Cal.	46	1917	All	1923	6 years	Gravel	Broke up badly - did not hold surface or line
Leonard	Concrete	Penna.	Atglen, Pa.	6	1914	All	1918	4 years	Cinder	Damaged by wreck
Maine	"	Maine Central	Hudson, Me.	69	1923-4	12	1936	-	Gravel	57 still in track
"	"	L.& N.E.	Tadmor, Pa.	994	1929-30	505	1938	-	Cinders	489 still in the tracks - Costs high
"	"	B. & M.	Boston	10	1929	-	-	-	Gravel	Still in tracks - Installed Yard Trks
Maryland	Cast Steel	Penna.	Lenover, Pa.	25	1919	All	1920	1 year	Cinders	-
[illegible]	Steel	P.& L.E.	Glassport	10	1912	All	1917	4 years	Slag	-
McCune	"	Monon. Conn.	Pittsburgh	45	1905	All	1907	2 years	Slag	-
McDonald	Concrete	A.T.& S.F.	Los Angeles	21	1907	All	1919	12 years	Gravel	Did not hold surface and broke up
"	"	L.A. St.Ry.	Los Angeles	4,323	1911	-	-	11 years	Concrete	Some still in paved street
Mackling & Smith	Steel	Penna.	Wilkinsburg	100	1910	All	1922	12 years	Steel	Impossible to hold gauge
Metal Cross Tie	Metal	N.& W.	Spark Tracks	568	1930	-	--	-	Cinder	Still in service
Metal Safety	"	Penna.	Wampum, Pa.	20	1922	All	[illegible]	5 years	Stone	Cracked and difficulty with keys
Metal Tie	"	B.& O.	Martinsburg, W.Va.	50	1909	All	1924	15 years	Stone	Maintenance was high
Miller	-	TRRofStL	St.Louis(Florissant Av)	100	1924	-	-	-	Cinder	Still in service
Moore	-	Sou.Pac.	Lafayette, La.	40	1917	All	-	-	-	Not satisfactory
Morgan	Steel Rails	Penna.	Atglen, Pa.	56	1915	All	1916	1 year	Cinder	-
Morrell	-	D.L.& W.	Scranton, Pa.	100	1892	-	-	--	—	No record of service available
Munslow	-	W.& L.E.	Jewett, O.	25	1916	All	-	-	--	Service cannot be located
Peerless	Steel	C.& A.	Chicago	201	1916	All	1932	16 years	Stone	Metal rusted - no strength in tie
Pennsylvania	"	Penna.	Atglen, Pa.	5	1913-4	All	1917	4 years	Cinder	--
Percival	Concrete	Florida E.C.	St.Augustine, Fla.	16	1906	All	1920	14 years	Rock	Removed acct.laying rail - Ties good
"	Concrete	P.& L.E.	McKees Rocks	25	1906	All	1908	2 years	Slag	-
"	"	Sou.Pacific	Bayou Sale	100	1910	All	1921	11 years	-	Installation not satisfactory
"	"	"	Edgewater, Texas	100	1906-8	All	1923	15 years	-	" " "
Price	-	Reading Co.	Germantown, Pa.	200	1893	-	-	-	-	No record of service available
Riegler	Concrete	Penna.	Emsworth, Pa.	15	1908	All	1938	30 years	Stone	-
Reinforced Concrete		A.T.& S.F.	Topeka, Kansas	6	1912	All	1915	3 years	Cinders	Broke up badly - did not hold surface
"	"	Col.& Sou.	Argo, Col.	3	1901	All	1902	1 year	-	-
"	"	N.Y.C. (U&D)	Rondout	-	1904	-	-	-	-	No record of service available
Rohm	Steel	Penna.	Sewickley	12	1910	All	1916	6 years	Cinder	Interlaced with wood ties
Saunders	-	I.& G.N.	Austin, Texas	-	1891	-	-	-	-	No record of service available
"	-	N.Y.C.	New York - G.C.T.	-	1891	-	-	-	-	No record of service available
Saxon	Concrete Blocks	A.T.& S.F.	Tecumseh, Okla.	33	1913-4	All	1915	2 years	Rock	Absolutely worthless
Schoen	See "Hartford"									
Seeley	Concrete without reinf.	Toledo Terminal	Toledo, O.	10	1903	All	1903	2 weeks	-	-
Seitz	Steel	C. C. C. & St.L.	Tiffin, O.	15	1904	All	1916	12 years	Gravel	-
"	"	Penna.	Emsworth, Pa.	49	1904	All	1906	2 years	-	-
Shane	Steel	D.& S.L.	Denver	26	1912-16	-	-	-	-	-
"	"	Penna.	Atglen, Pa.	100	1916	All	1918	2 years	Cinder	Removed acct.failure of insulation
"	"	Union Pac.	Denver	33	1912	All	1916	4 years	-	-
Silver	"	N.Y.C.	Spuyten Duyvil	5	1918	All	1923	5 years	Stone	Concrete filling broken - metal exposed
"	"	Penna.	W.Morrisville, Pa.	102	1923	All	1931	8 years	Cinder	
"	"	"	Atglen, Pa.	148	1922	All	1923	1 year	-	-
Simplex	Steel & Conc.	Alton	Near Chicago	63	1912	All	11917	5 years	Stone	Insulation causing trouble block signals
Snyder	Composite	Penna.	Derry Yard	983	1906	-	-	-	Cinder	979 still in track in 1938
"	"	"	Pitcairn Yard	174	1923	-	-	-	Cinder	174 " " " "
"	"	" (Corn.&Leb)	Mt. Gretna, Pa.	200	1906	All	1918	12 years	Cinder	Steel shell filled with concrete
"	"	Pennsylvania	Pittsburgh Division	2256	1907	1102	1939	-	-	1153 still in tracks
Standard	Steel	C.& W.I.	Chicago	500	1889	All	-	-	-	No record of service available
"	"	D.& H.	Saratoga Springs	1,500	1890	All	1891	1 year	-	-
"	"	Long Island	Long Island	500	1891	All	1894	3 years	-	No information available
"	"	P.& R.	Philadelphia, Pa.	1,000	1891	All	1894	3 years	-	-
"	"	Penna.	Lenover, Pa.	500	1915	All	1921	6 years	Cinder	-
"	"	P.& L.E.	Glassport, Pa.	20	1914	All	1926	12 years	Slag	-
Stoneback	-	H.& B.T.M.	Huntingdon, Pa.	3	1915	All	1920	5 years	-	-
Taylor or Columbian		Sante Fe	Streator, Ill.	22	1887	All	1894	7 years	-	-
Toucey	-	N.Y.C.	New York (G.C.T.)	1,000	1885	All	-	-	-	No record of service available
Travis	-	P.W.& B.	Chester Creek Br.	100	[illegible]	All	-	-	-	No record of service available
Universal	Steel	A.T.& S.F.	Braddock, Kansas	117	1911	All	1920	9 years	-	-
"	"	A.T.& S.F.	Chicago, Ill.	65	1911	All	1920	9 years	-	—
"	Steel & Conc.	C.B.& Q.	Chicago, Ill.	100	1911	All	[illegible]	6 years	-	Installation not satisfactory
"	"	N.Y.C.	New York City	100	1911	All	1920	9 years	Stone	-
"	"	Penna.	Emsworth, Pa.	100	1910	All	1913	2½ years	-	-
"	"	P.& L.E.	Pittsburgh	100	1911	All	1916	5 years	Slag	-
Vaples	Concrete	Penna.	Atglen, Pa.	6	1916	All	1917	1 year	Cinder	-
Weber	See "LaGuna"									
Webb	-	Penna.	Huntingdon, Pa.	880	1887	All	-	-	-	No record of service available
"	-	"	Menlo Park, N.J.	880	1887	All	-	—	-	No record of service available
Weller & Reese	Concrete	A.T.& S.F.	Los Angeles	9	1911	All	1913	2 years	-	-
Willis	"	Penna.	Manhattan	24	1927	All	1931	4 years	-	Removed when track circuit installed
Wyckoff	Combination	B.& O.	Baltimore	4	1921	All	1926	5 years	-	-

C. C. C. & St. L. Railway
Cincinnati, Ohio, July 1, 1939.

TABLE A

CROSS TIES LAID IN REPLACEMENT - CLASS I STEAM ROADS, UNITED STATES AND LARGE CANADIAN ROADS

Calendar year ended December 31, 1938

Road	Wooden ties untreated (U)		Wooden ties treated (T)		Ties other than wood(S) & secondhand reapplied	Total ties applied	Miles of maintained tracks (item 24)	Estimated total cross ties in all maintained tracks (item 25)	Equated gross ton-miles a (thousands)
	Number	Average cost#	Number	Average cost#					
1	2	3	4	5	6	7	8	9	10
NEW ENGLAND REGION:									
Bangor & Aroostook	157 788	$0.57	-	-	-	157 788	830.18	2 376 427	1 332 798
Boston & Maine	29 860	0.84	205 285	$1.53	-	235 145	3 228.86	9 558 000	12 294 148
Canadian Nat.Lines in New Eng.	7 351	0.64	25 121	1.20	-	32 472	250.16	768 456	527 637
Canadian Pacific (lines in Me.)	-	-	22 813	1.44	-	22 813	213.19	618 174	1 107 489
Canadian Pacific (lines in Vt.)	-	-	7 282	1.26	-	7 282	131.36	410 085	506 573
Central Vermont	1 113	0.79	49 224	1.52	-	50 337	503.63	1 438 029	1 912 245
Maine Central	137 477	0.79	111 732	1.73	-	249 209	1 232.58	3 738 530	3 146 728
New York Connecting	-	-	7 728	1.52	-	7 728	25.98	82 831	293 412
New York,New Haven & Hartford	-	-	288 774	1.29	-	288 774	4 122.91	12 500 790	18 102 201
Rutland	-	-	28 726	1.33	*1 950	30 676	499.93	1 551 000	1 368 131
GREAT LAKES REGION:									
Ann Arbor	-	-	36 572	1.42	-	36 572	407.62	1 230 122	1 252 217
Cambria & Indiana	12 884	0.30	8 929	2.08	-	21 813	63.70	166 600	124 000
Delaware & Hudson	269	1.08	106 033	2.12	(S) 196	106 498	1 455.81	4 445 532	7 469 750
Delaware,Lackawanna & Western	-	-	135 564	1.67	*17 998	153 562	2 375.80	6 889 820	15 279 535
Detroit & Mackinac	34 420	0.41	11 365	0.71	-	45 785	273.69	880 222	281 274
Detroit & Toledo Shore Line	-	-	12 427	1.80	*139	12 566	151.58	462 344	557 928
Erie (incl.Chi.& Erie)	13	1.21	434 490	1.50	-	434 503	4 905.11	14 445 958	28 378 544
Grand Trunk Western	14	0.93	280 776	1.60	-	280 790	1 947.92	6 155 427	6 831 432
Lehigh & Hudson River	-	-	10 898	2.28	*118	11 016	120.70	317 950	564 042
Lehigh & New England	66	0.59	16 500	1.56	-	16 566	278.84	836 776	682 872
Lehigh Valley	-	-	128 044	1.36	-	128 044	2 755.10	8 162 459	13 793 073
Monongahela	-	-	25 052	1.74	-	25 052	241.91	700 282	743 321
Montour	987	0.96	5 884	2.21	-	6 871	77.76	217 407	253 139
New Jersey & New York	-	-	2 499	1.52	-	2 499	56.49	162 932	178 839
New York Central	3 182	2.18	1 826 106	1.50	*16 195	1 845 483	22 081.04	68 760 234	128 825 385
New York, Chicago & St.Louis	-	-	235 856	1.57	-	235 856	2 522.01	7 906 495	15 310 657
New York,Ontario & Western	-	-	37 836	1.48	-	37 836	887.03	2 521 167	2 362 732
New York,Susquehanna & Western	-	-	16 725	1.43	-	16 725	228.97	665 015	369 428
Pere Marquette	-	-	432 838	1.70	-	432 838	2 832.98	8 568 714	9 112 793
Pittsburgh & Lake Erie	247	1.22	29 763	1.97	-	30 010	931.67	2 791 080	3 107 184
Pittsburg & Shawmut	14 029	1.17	13 169	1.71	-	27 198	121.69	339 318	120 393
Pittsburgh & West Virginia	19 007	1.28	33 446	2.17	*137	52 590	198.25	576 398	737 989
Pittsburg,Shawmut & Northern	25 001	0.99	-	-	-	25 001	221.70	651 415	229 619
Wabash	129	1.14	488 794	1.42	-	488 923	3 177.98	10 016 760	17 590 838
CENTRAL EASTERN REGION:									
Akron,Canton & Youngstown	15 630	1.09	19 560	1.08	-	35 190	213.49	614 791	394 245
Baltimore & Ohio	1 727	0.84	694 863	1.[illegible]7	-	696 590	10 674.39	30 349 122	54 063 889
Bessemer & Lake Erie	273	0.80	104 689	2.20	(S) 180	105 142	494.13	1 529 696	2 046 917
Central R.R.of New Jersey	-	-	59 957	1.68	-	59 957	1 490.75	4 187 218	7 236 949
Chicago & Eastern Illinois	-	-	158 075	[illegible]	-	158 075	1 423.79	4 415 030	5 512 920
Chicago & Illinois Midland	-	-	12 503	1.77	-	12 503	105.13	508 090	534 512
Chicago,Indpls.& Louisville	[illegible]	0.76	[illegible]	1.14	*3 175	[illegible]	[illegible]	2 517 602	3 188 462
Detroit,Toledo & Ironton	3 317	[illegible]	63 594	1.35	-	66 911	610.55	1 758 384	1 222 206
Elgin,Joliet & Eastern	-	-	84 120	1.68	*1 408	85 528	860.03	2 698 128	2 154 005
Illinois Terminal	16 485	[illegible]	37 800	[illegible]	*3 502	57 787	649.18	1 947 540	1 273 056
Long Island	-	-	49 236	1.88	-	49 236	822.66	2 439 272	6 580 309
Missouri-Illinois	36 465	0.75	30 296	1.31	-	66 761	239.62	747 000	200 381
Pennsylvania	2 788	0.61	1 271 512	1.54	t 38	1 274 338	21 410.80	59 948 430	137 602 234
Penna.-Reading Seashore Lines	-	-	50 095	2.26	-	50 095	663.02	1 614 900	1 555 350
Reading Co.	-	-	84 951	1.74	(S) 22	84 973	3 046.24	8 361 388	13 036 542
Staten Island Rapid Transit	-	-	4 085	0.94	-	4 085	90.87	251 963	413 309
Western Maryland	34 556	1.01	118 184	1.62	-	152 740	1 189.61	3 426 068	4 648 376
Wheeling & Lake Erie	156	1.17	76 059	1.36	*22 055	98 270	844.46	2 530 970	2 836 415
POCAHONTAS REGION:									
Chesapeake & Ohio	2 022	0.61	433 712	1.22	-	435 734	5 102.38	15 698 559	42 312 973
[illegible]	-	-	[illegible]	[illegible]	*7 021	[illegible]	[illegible]	[illegible]	30 566 194
[illegible]	24	1.12	100 398	1.63	*225	100 647	374.75	1 070 700	3 480 624
Virginian	385	0.82	154 651	1.47	*1 728	156 764	569.94	2 708 993	6 064 214
SOUTHERN REGION:									
Alabama Great Southern	4 472	1.13	77 452	1.46	-	81 924	548.70	1 705 664	2 700 641
Atlanta & West Point	12 265	1.23	10 720	0.68	-	22 985	141.51	433 693	1 230 282
Western Ry.of Alabama	23 648	1.24	8 139	0.90	-	31 787	181.81	552 134	
Atlanta,Birmingham & Coast	53 830	0.76	66 495	1.15	-	120 325	798.05	2 305 100	1 614 844
Atlantic Coast Line	510 876	0.84	371 969	1.26	-	882 845	6 848.81	19 892 369	20 514 890
Central of Georgia	17 254	0.96	323 943	1.03	-	341 197	2 349.68	6 905 700	6 794 771
Charleston & Western Carolina	62 186	1.09	-	-	-	62 186	427.22	1 233 652	751 512
Cincinnati,New Orleans & Tex.Pac.	-	-	66 622	1.65	-	66 622	772.90	2 405 159	6 354 975
Clinchfield	53 262	0.71	46 657	1.43	-	99 919	395.75	1 203 067	2 230 666
Columbus & Greenville	18 362	0.63	22 746	1.30	-	41 108	202.49	641 488	365 134
Florida East Coast	180 697	0.89	-	-	-	180 697	1 348.19	3 869 295	4 126 622
Georgia R.R.	65 683	1.20	3 972	1.79	-	69 655	431.44	1 320 194	1 358 905
Georgia & Florida	82 109	0.64	-	-	-	82 109	452.45	1 221 615	418 705
Georgia,Southern & Florida	36 332	1.03	-	-	-	36 332	471.46	1 482 401	1 175 551
Gulf & Ship Island	55	0.56	59 924	1.04	*726	60 705	309.58	954 889	416 401
Gulf,Mobile & Northern	31 983	0.65	209 501	1.13	*9 505	250 989	940.00	2 977 915	2 210 625
Illinois Central	71 794	0.73	1 071 228	1.09	*750	1 143 772	7 779.15	23 689 388	45 173 904
Yazoo & Mississippi Valley	139 186	0.79	221 593	1.03	-	360 779	2 123.12	6 487 476	
Louisville & Nashville	39 731	1.11	739 028	1.36	-	778 759	6 919.45	19 724 803	33 092 727
Mississippi Central	4 442	0.52	32 715	1.05	-	37 157	168.10	532 453	209 157
Mobile & Ohio	278 006	0.70	80 060	1.08	-	358 066	1 197.20	3 792 717	5 030 784
Nashville,Chattanooga & St.Louis	-	-	166 766	1.37	*720	167 486	1 529.13	4 188 287	5 530 355
New Orleans & Northeastern	775	0.86	31 746	1.45	-	32 521	281.34	874 621	1 240 433
Norfolk Southern	268 368	0.69	-	-	-	268 368	960.63	2 939 528	1 293 259
Northern Alabama	20 205	0.71	26 947	1.69	-	47 152	119.81	374 000	184 260
Seaboard Air Line	477 188	0.93	529 752	1.13	-	1 006 940	5 370.35	16 265 123	18 370 749
Southern Ry.	867 064	1.06	905 853	1.53	-	1 772 917	8 667.91	27 114 703	35 718 771
Tennessee Central	67 332	0.72	-	-	-	67 332	337.19	1 021 017	684 194

TABLE A

CROSS TIES LAID IN REPLACEMENT - CLASS I STEAM ROADS, UNITED STATES AND LARGE CANADIAN ROADS

Calendar year ended December 31, 1938

Road	Wooden ties untreated (U)		Wooden ties treated (T)		Ties other than wood(S) & secondhand reapplied	Total ties applied	Miles of maintained tracks (item 24)	Estimated total cross ties in all maintained tracks (item 25)	Equated gross ton-miles a (thousands)
	Number	Average cost#	Number	Average cost#					
1	2	3	4	5	6	7	8	9	10
NORTHWESTERN REGION:									
Chicago & North Western	64 950	$0.58	1 612 981	$1.05	-	1 677 931	12 112.78	35 867 701	34 185 731
Chicago Great Western	136 775	1.02	161 889	1.49	-	298 664	1 697.26	5 575 330	3 145 910
Chicago,Milwaukee,St.Paul & Pac.	730 745	0.51	1 001 923	1.37	-	1 732 668	13 898.21	42 657 160	42 297 029
Chicago,St.Paul,Minpls.& Omaha	75 120	0.69	329 347	1.11	-	404 467	2 227.12	6 600 910	6 553 219
Duluth,Missabe & Iron Range	26 763	0.85	42 331	1.59	-	69 094	1 096.66	3 292 353	1 042 976
Duluth,South Shore & Atlantic	102 509	0.61	-	-	-	102 509	531.52	1 503 292	611 406
Duluth,Winnipeg & Pacific	56 038	0.58	11 419	1.54	-	67 457	210.66	631 980	390 487
Great Northern	21 392	0.48	1 025 515	1.26	*56 881	1 103 788	9 891.41	30 390 049	31 0[illegible]
Green Bay & Western	67 324	0.75	23 982	1.62	-	91 306	284.99	624 477	449 395
Lake Superior & Ishpeming	36 958	0.61	2 388	1.73	-	39 346	234.75	704 250	97 708
Minneapolis & St.Louis	203 252	0.79	129 647	1.28	-	332 899	1 684.27	5 114 326	2 921 275
Minneapolis,St.Paul & S.S.Marie	598 251	0.58	204 058	1.28	-	802 309	4 981.69	14 674 292	9 470 160
Northern Pacific	24 378	0.53	1 133 420	1.14	-	1 157 798	9 073.52	26 344 0[illegible]6	24 690 071
Spokane International	63 973	0.46	28	1.71	-	64 001	194.42	550 095	214 878
Spokane,Portland & Seattle	147 419	0.59	110 235	1.46	-	257 654	1 088.69	3 517 520	2 717 444
CENTRAL WESTERN REGION:									
Alton R.R.	231 877	1.11	143 787	1.91	*2 665	378 329	1 513.00	4 571 574	6 299 952
Atchison,Topeka & Santa Fe	701	1.22	1 641 172	1.20	-	1 641 873	19 435.85	59 026 676	72 467 373
Chicago,Burlington & Quincy	-	-	1 881 442	1.31	*51 883	1 933 325	12 319.99	38 044 127	42 599 069
Chicago,Rock Island & Pacific	788	0.59	1 111 066	1.05	-	1 111 854	9 207.55	27 427 475	(35 641 916
Chicago,Rock Island & Gulf	-	-	62 058	1.06	*3 969	66 027	756.72	2 316 424	(
Colorado & Southern	3 956	0.42	66 186	1.23	*14 530	84 672	902.45	2 707 550	2 554 745
Denver & Rio Grande Western	3 697	0.27	265 511	1.16	(*111 407) (n 93 011)	473 626	3 318.09	10 352 896	10 312 888
Denver & Salt Lake	-	-	13 067	1.45	-	13 067	312.76	955 169	683 444
Fort Worth & Denver City	205	0.14	90 038	1.12	*4 516	94 759	955.24	2 875 330	2 981 546
Nevada Northern	30 887	0.88	-	-	-	30 887	190.48	546 690	109 527
Northwestern Pacific	47 727	0.80	-	-	-	47 727	459.05	1 338 075	883 417
Southern Pacific	143 155	0.73	1 082 367	1.21	-	1 225 522	12 362.83	37 386 427	65 853 439
Toledo,Peoria & Western	781	0.57	97 400	1.43	-	98 181	275.86	873 924	654 476
Union Pacific	22 670	0.62	1 947 111	1.14	-	1 969 781	13 145.47	37 140 465	76 984 672
Utah Ry.	3 427	0.70	4 838	2.18	*748	9 013	85.00	228 225	179 190
Western Pacific	184 319	0.81	177 101	1.52	-	361 420	1 486.14	4 411 000	7 380 076
SOUTHWESTERN REGION:									
Burlington-Rock Island	-	-	12 627	0.91	-	12 627	213.55	668 412	554 876
Gulf Coast Lines:									
Beaumont,Sour Lake & Western	-	-	14 503	1.07	-	14 503	139.74	416 100	(4 731 098
New Orleans,Texas & Mexico	3 973	0.56	45 261	1.07	-	49 234	227.07	694 100	(
St.Louis,Brownsville & Mexico	-	-	86 668	1.02	-	86 668	753.69	2 279 500	(
San Antonio,Uvalde & Gulf	-	-	59 315	1.10	-	59 315	360.71	1 040 000	(
International-Great Northern	-	-	156 736	0.99	-	156 736	1 487.46	4 455 900	5 [illegible] 423
Kansas City Southern	-	-	172 677	1.04	-	172 677	1 256.91	3 982 797	4 555 447
Kansas,Oklahoma & Gulf	449	0.60	60 953	1.06	-	61 402	356.84	1 070 096	829 767
Louisiana & Arkansas	34 304	0.59	126 891	0.84	-	161 195	718.83	2 270 272	1 807 574
Louisiana,Arkansas & Texas	79 335	0.57	23 204	0.90	-	102 539	245.30	742 030	372 838
Midland Valley	404	0.50	35 209	1.01	-	35 613	386.61	1 147 689	360 734
Missouri & Arkansas	123 414	0.42	-	-	-	123 414	356.86	1 111 909	330 817
Missouri-Kansas-Texas	8 869	0.79	396 895	1.07	-	405 764	4 096.49	12 897 900	13 063 711
Missouri Pacific	116 063	0.54	1 431 583	1.12	-	1 547 646	9 028.02	27 949 700	38 523 670
Oklahoma City-Ada-Atoka	31 723	0.55	3 070	1.21	-	34 793	143.36	430 384	74 530
St.Louis-San Francisco	110 870	0.67	1 059 562	1.10	-	1 170 432	6 492.44	20 447 348	19 197 314
St.Louis,San Francisco & Texas	9 321	0.68	29 993	1.07	-	39 314	258.09	814 216	450 991
St.Louis Southwestern	-	-	305 150	1.11	*17 620	322 770	1 925.89	6 107 161	7 537 686
Texas & New Orleans	109	0.98	748 317	0.97	-	748 426	5 633.80	15 516 858	17 004 867
Texas & Pacific	2	0.38	231 941	1.03	-	231 943	2 477.34	7 234 126	11 450 985
Texas Mexican	60	0.25	27 693	1.16	-	27 753	205.58	651 277	190 664
CANADIAN ROADS:									
Canadian National	4 057 399	0.60	1 739 782	1.28	-	5 797 181	27 686	79 104 106	61 368 193
Canadian Pacific	1 885 390	0.52	1 673 691	1.23	-	3 559 081	21 467	60 197 329	53 921 889
Temiskaming & Northern Ontario	136 462	0.72	217	1.89	-	136 679	545	1 548 900	1 484 520

a Maischaider formula. n Narrow gage ties. t Tunnel ties. * Secondhand ties.

These are storekeepers' average costs of ties charged out and used. They are not the actual costs or the prices paid for ties purchased during the period.

Note: Compiled from annual reports of Class I railways to the Interstate Commerce Commission.

Compiled by
Association of American Railroads
Bureau of Railway Economics
Washington, D.C.

TABLE B

WOODEN CROSS TIES LAID IN REPLACEMENT (TREATED & UNTREATED) ON LEADING RAILROADS IN THE UNITED STATES AND CANADA

Calendar year ended December 31, 1938

Note: All figures are exclusive of bridge & switch ties

Road	Miles of maintained track occupied by wooden cross ties (Col.8-Table A)	Average number of wooden cross ties per mile of maintained track	Total number of wooden cross ties renewed 1938	Number of wooden cross ties renewed per mile of maintained track	Weighted average cost per wooden cross tie	Cost of wooden cross tie renewals per mile of maintained track	Per cent wooden cross tie renewals to all ties in tracks	Equated gross ton-miles per mile of maintained track	Cost of wooden cross tie renewals per thousand equated gross ton-miles
1	2	3	4	5	6	7	8	9	10
NEW ENGLAND REGION.									(cents)
Bangor & Aroostook	830.18	2 863	157 785	190	$1.57	$109	6.6	1 605 4[illegible]	6.76
Boston & Maine	3 220.86	[illegible]	235 145	73	1.44	105	2.5	3 807 582	2.76
Canadian Nat. Lines in New Eng.	250.16	[illegible]	32 47[illegible]	130	1.07	139	4.2	2 109 190	6.61
Canadian Pacific (lines in Me.)	213.19	2 900	22 813	107	1.44	154	3.7	5 194 845	2.96
Canadian Pacific (lines in Vt.)	131.30	3 122	7 20[illegible]	55	1.26	[illegible]	1.8	[illegible]	[illegible]
Central Vermont	503.63	2 855	50 337	100	1.50	150	3.5	3 796 924	3.96
Maine Central	1 232.58	3 033	249 [illegible]	202	1.21	245	6.7	[illegible]	[illegible]
New York Connecting	25.98	3 188	7 72[illegible]	297	1.52	45[illegible]	9.3	11 293 764	4.01
New York, New Haven & Hartford	4 1[illegible].91	3 032	288 774	70	1.29	90	2.3	4 390 637	2.05
Rutland	4[illegible]9.93	[illegible]	[illegible]	57	1.3[illegible]	7[illegible]	1.9	[illegible]	[illegible]
GREAT LAKES REGION.									
Ann Arbor	407.62	[illegible]	36 57[illegible]	90	1.42	127	3.0	3 072 021	4.13
Cambria & Indiana	63.70	2 615	21 81[illegible]	342	1.39	475	[illegible]	1 946 625	24.38
Delaware & Hudson	1 455.81	3 [illegible]54	106 302	73	2.12	154	2.4	5 130 992	3.01
Delaware, Lackawanna & Western	2 375.80	[illegible]	135 564	57	1.67	95	[illegible]	6 431 322	1.48
Detroit & Mackinac	[illegible]	2 791	42 755	156	0.49	76	5.[illegible]	927 [illegible]	[illegible]
Detroit & Toledo Shore Line	151.56	3 050	12 4[illegible]7	82	1.80	147	2.7	[illegible] 749	4.00
Erie (Incl.Chgo.& Erie)	4 9[illegible].11	[illegible]	404 5[illegible]	82	1.50	124	2.8	5 785 506	2.14
Grand Trunk Western	1 9[illegible].92	3 160	280 790	144	1.60	230	4.6	3 507 039	6.56
Lehigh & Hudson River	120.70	2 634	10 898	90	2.28	206	3.4	4 673 090	4.40
Lehigh & New England	278.84	3 001	16 566	59	1.56	93	2.0	2 448 974	3.78
Lehigh Valley	2 755.10	[illegible]	12[illegible] [illegible]44	46	1.36	63	1.6	5 007 104	1.26
Monongahela	241.91	2 895	2[illegible] [illegible]52	104	1.73	179	[illegible]	3 072 717	5.83
Montour	77.76	2 796	6 871	88	2.03	179	3.[illegible]	3 255 388	5.50
New Jersey & New York	56.49	2 884	2 499	44	1.52	67	1.5	3 165 852	2.13
New York Central	[illegible]	3 114	1 829 288	63	1.5[illegible]	12[illegible]	2.1	[illegible]	1.14
New York, Chicago & St. Louis	[illegible].01	3 135	235 856	94	1.57	147	3.0	[illegible] 815	2.4[illegible]
New York, Ontario & Western	887.03	2 [illegible]42	37 836	43	1.48	63	1.5	[illegible] 644	2.37
New York, Susquehanna & Western	228.97	2 904	16 725	73	1.43	104	2.5	[illegible] 434	6.47
Pere Marquette	2 832.98	[illegible]	432 [illegible]	153	1.70	259	5.1	3 216 681	8.05
Pittsburgh & Lake Erie	931.67	2 996	30 [illegible]	32	1.96	63	1.1	[illegible] 5 069	1.89
Pittsburg & Shawmut	121.69	2 75[illegible]	27 198	224	1.43	320	8.[illegible]	989 342	32.31
Pittsburgh & West Virginia	198.25	2 9[illegible]7	52 453	265	1.84	488	9.1	3 722 517	13.11
Pittsburg, Shawmut & Northern	221.70	2 936	25 001	113	0.99	112	3.8	1 035 719	10.79
Wabash	3 199.98	3 130	488 923	153	1.42	216	4.9	5 497 171	3.94
CENTRAL EASTERN REGION.									
Akron, Canton & Youngstown	[illegible].49	2 8[illegible]	35 190	165	1.08	179	5.7	1 846 667	9.68
Baltimore & Ohio	[illegible]	2 [illegible]43	690 590	65	1.57	103	2.3	5 064 822	2.02
Bessemer & Lake Erie	494.13	3 096	104 962	212	2.20	467	6.9	4 142 467	11.28
Central R R of New Jersey	1 490.75	2 909	59 957	40	1.68	68	1.4	4 854 569	1.39
Chicago & Eastern Illinois	1 423.79	3 101	158 075	111	1.20	134	3.6	3 872 004	3.45
Chicago & Illinois Midland	16[illegible].13	3 077	12 503	76	1.77	134	2.5	5 174 784	2.60
Chicago, Indpls.& Louisville	82[illegible].76	3 [illegible]67	149 852	183	1.13	206	6.0	3 884 768	5.30
Detroit, Toledo & Ironton	610.55	2 880	6[illegible] [illegible]11	110	1.31	143	3.8	2 001 811	7.17
Elgin, Joliet & Eastern	[illegible]	3 137	84 120	98	1.68	164	3.[illegible]	2 504 570	6.57
Illinois Terminal	649.18	3 000	54 285	84	1.14	95	2.8	1 [illegible]61 [illegible]	4.85
Long Island	822.66	2 965	49 [illegible]36	60	1.88	113	2.0	7 998 820	1.41
Missouri-Illinois	239.62	3 117	66 [illegible]1	279	1.01	280	8.9	836 245	33.51
[illegible]	[illegible]	[illegible]	1 [illegible]	[illegible]	1.53	93	[illegible]	6 426 768	1.44
Pennsylvania-Reading Seashore Lines	[illegible]	2 737	50 095	76	2.26	171	2.8	2 346 581	7.27
Reading Company	2 [illegible]46.24	2 745	84 951	[illegible]	1.74	48	1.6	4 476 5[illegible]	1.08
Staten Island Rapid Transit	9[illegible].07	2 773	4 [illegible]85	52	0.94	49	1.9	4 548 355	1.07
Western Maryland	1 189.61	2 [illegible]00	152 740	128	1.48	190	4.5	3 907 479	4.87
Wheeling & Lake Erie	844.46	2 997	76 215	90	1.36	122	3.0	3 358 851	3.65
POCAHONTAS REGION.									
Chesapeake & Ohio	5 102.38	3 077	435 734	85	1.22	104	2.8	8 292 791	1.25
Norfolk & Western	4 3[illegible]9.65	3 100	95 075	22	1.22	27	0.7	7 092 500	0.38
Richmond, Fred.& Potomac	374.75	2 857	100 447	268	1.63	437	9.4	9 [illegible]67 85[illegible]	4.71
Virginian	869.94	3 114	155 036	178	1.47	262	5.7	7 66[illegible] 544	3.42
SOUTHERN REGION.									
Alabama Great Southern	54[illegible].70	3 1[illegible]9	81 924	149	1.44	215	4.8	4 936 470	4.36
Atlanta & West Point	141.51	3 [illegible]65	22 985	162	0.97	158	5.3	3 805 153	4.79
Western Ry.of Alabama	181.81	3 037	31 787	175	1.15	201	5.8		
Atlanta, Birmingham & Coast	798.05	2 888	120 325	151	0.98	148	5.2	2 023 487	7.34
Atlantic Coast Line	6 848.81	2 905	882 845	129	1.02	131	4.4	2 995 395	4.38
Central of Georgia	2 349.68	2 9[illegible]9	341 197	145	1.03	149	4.9	2 891 766	5.15
Charleston & Western Carolina	427.22	2 888	62 186	146	1.09	159	5.0	1 759 075	9.04
Cincinnati, New Orleans & Tex.Pac.	772.90	3 112	66 622	86	1.65	142	2.8	8 222 247	1.73
Clinchfield	3[illegible]5.75	3 [illegible]40	79 919	252	1.04	263	8.3	5 636 553	4.67
Columbia & Greenville	202.49	3 168	41 108	203	1.00	203	6.4	1 803 220	11.25
Florida East Coast	1 348.19	2 870	180 697	134	0.89	119	4.7	3 060 861	3.89
Georgia	431.44	3 060	69 655	161	1.23	199	5.3	3 149 696	6.31
Georgia & Florida	452.45	2 700	82 109	181	0.64	116	6.7	925 417	12.57
Georgia, Southern & Florida	471.46	3 144	36 332	77	1.03	80	2.5	2 493 427	3.19
Gulf & Ship Island	309.58	3 084	59 979	194	1.04	202	6.3	1 345 051	15.02
Gulf, Mobile & Northern	940.00	3 168	241 484	257	1.07	274	8.1	2 351 729	11.66
Illinois Central	7 779.15	3 045	1 143 022	147	1.06	156	4.8	4 561 975	3.44
Yazoo & Miss.Valley	2 123.12	3 056	360 779	170	0.94	159	5.6		
Louisville & Nashville	6 919.45	2 851	778 759	113	1.35	152	3.9	4 782 566	3.17
Mississippi Central	168.10	3 167	37 157	221	0.98	218	7.0	1 244 242	17.49
Mobile & Ohio	1 197.20	3 168	358 066	299	0.78	234	9.4	4 202 125	5.57
Nashville, Chatt.& St.Louis	1 529.13	2 739	166 766	109	1.37	149	4.0	3 616 668	4.13
New Orleans & Northeastern	281.34	3 109	32 521	116	1.43	165	3.7	4 409 018	3.75
Norfolk Southern	960.63	3 060	268 368	279	0.69	192	9.1	1 346 261	14.30
Northern Alabama	119.81	3 122	47 152	394	1.27	501	12.6	1 537 9[illegible]5	32.58
Seaboard Air Line	5 370.35	3 029	1 006 940	187	1.04	194	6.2	3 420 773	5.68
Southern Ry.	8 667.91	3 128	1 772 917	205	1.30	266	6.5	4 120 805	6.46
Tennessee Central	337.19	3 028	67 332	200	0.72	143	6.6	2 029 105	7.05

TABLE B

WOODEN CROSS TIES LAID IN REPLACEMENT (TREATED & UNTREATED) ON LEADING RAILROADS IN THE UNITED STATES AND CANADA

Calendar year ended December 31, 1938

Note. All figures are exclusive of bridge & switch ties

Road	Miles of maintained track occupied by wooden cross ties (Col.8-Table A)	Average number of wooden cross ties per mile of maintained track	Total number of wooden cross ties renewed 1938	Number of wooden cross ties renewed per mile of maintained track	Weighted average cost per wooden cross tie	Cost of wooden cross tie renewals per mile of maintained track	Per cent wooden cross tie renewals to all ties in tracks	Equated gross ton-miles per mile of maintained track	Cost of wooden cross tie renewals per thousand equated gross ton-miles
1	2	3	4	5	6	7	8	9	10
NORTHWESTERN REGION:									
Chicago & North Western	12 112.78	2 961	1 677 931	139	$1.03	$143	4.7	2 822 286	(cents) 5.0[illegible]
Chicago Great Western	1 897.56	2 750	295 664	157	1.27	200	5.3	4 295 164	4.66
Chicago, Milwaukee, St. Paul & Pac.	1[illegible] 898.21	3 069	1 732 666	125	1.06	125	4.1	3 [illegible]47 012	4.12
Chicago, St. Paul, Minpls. & Omaha	2 227.12	2 964	404 467	182	1.03	187	6.1	2 942 463	6.36
Duluth, Missabe & Iron Range	1 076.66	3 0[illegible]	6[illegible] [illegible]94	63	1.30	82	2.1	1 490 102	5.47
Duluth, South Shore & Atlantic	[illegible]31.[illegible]2	2 628	1[illegible] [illegible]9	193	0.61	118	6.8	1 150 397	1[illegible].[illegible]4
Duluth, Winnipeg & Pacific	210.66	3 000	67 457	32[illegible]	0.74	238	10.7	1 053 636	1[illegible].03
Great Northern	9 891.41	3 093	1 046 907	106	1.24	132	3.4	3 137 381	4.20
Green Bay & Western	[illegible]94.99	2 8[illegible]	91 306	32[illegible]	0.98	314	11.1	1 576 [illegible]	1[illegible].9[illegible]
Lake Superior & Ishpeming	234.75	3 000	[illegible] 346	168	0.68	114	5.6	416 222	27.40
Minneapolis & St. Louis	1 684.27	3 [illegible]7	[illegible]32 899	198	0.98	193	6.5	1 734 458	11.14
Minneapolis, St. Paul & S.S. Marie	4 981.69	2 946	8[illegible]2 [illegible]9	161	0.76	[illegible]	5.5	1 900 993	6.43
Northern Pacific	9 [illegible]73.52	2 9[illegible]	1 157 [illegible]49	126	1.15	144	4.4	2 721 774	5.29
Spokane International	194.42	2 829	64 001	329	0.46	150	11.6	1 105 [illegible]	1[illegible].58
Spokane, Portland & Seattle	1 088.69	3 231	257 6[illegible]4	237	0.96	228	7.3	2 681 612	8.51
CENTRAL WESTERN REGION:									
Alton	1 513.00	[illegible]	375 664	24[illegible]	1.42	352	8.2	4 163 551	8.4[illegible]
Atchison, Topeka & Santa Fe	19 435.85	3 [illegible]7	1 641 873	84	1.20	102	2.8	3 728 541	2.73
Chicago, Burlington & Quincy	12 319.99	3 [illegible]	1 881 442	153	1.31	201	4.9	3 457 719	5.80
Chicago, Rock Island & Pacific	9 [illegible]7.55	2 9[illegible]	1 111 5[illegible]4	121	1.0[illegible]	124	4.1	3 576 972	3.46
Chicago, Rock Island & Gulf	756.72	3 [illegible]1	[illegible] 58	82	1.06	87	2.7		
Colorado & Southern	9[illegible]2.45	3 000	7[illegible] 142	78	1.19	92	[illegible].6	2 863 737	3.[illegible]9
Denver & Rio Grande Western	[illegible] 318.09	[illegible] 12[illegible]	[illegible]64 [illegible]8	81	1.15	93	2.6	3 1[illegible]	2.99
Denver & Salt Lake	[illegible].76	[illegible]4	13 067	42	1.45	60	1.4	2 183 203	2.[illegible]
Fort Worth & Denver City	9[illegible].24	3 010	9[illegible] [illegible]43	94	1.12	106	3.1	3 122 253	3.38
Nevada Northern	1[illegible].4[illegible]	2 [illegible]	[illegible]0 88[illegible]	162	0.88	143	5.6	575 005	24.83
Northwestern Pacific	45[illegible]	2 915	47 727	104	0.80	84	3.6	1 924 446	4.35
Southern Pacific	1[illegible] 362.8[illegible]	3 [illegible]4	1 225 522	99	1.15	114	3.3	5 326 729	2.14
Toledo, Peoria & Western	275.86	3 160	98 101	356	1.42	505	11.2	2 372 493	21.27
Union Pacific	1[illegible] 14[illegible].47	2 [illegible]5	[illegible] [illegible]69 761	150	1.14	170	5.3	5 056 365	2.9[illegible]
Utah	[illegible]5.00	[illegible] 655	8 265	97	1.37	133	3.6	2 108 118	7.24
Western Pacific	1 4[illegible].14	3 468	361 42[illegible]	243	1.16	282	8.2	4 965 936	5.67
SOUTHWESTERN REGION:									
Burlington-Rock Island	[illegible]	[illegible]	1[illegible] [illegible]	59	0.91	54	1.9	[illegible] 598 342	2.08
Gulf Coast Lines:									
Beaumont, Sour Lake & Western	1[illegible].74	2 978	14 5[illegible]	104	1.07	111	3.5	3 194 076	4.64
New Orleans, Texas & Mexico	[illegible]7.[illegible]7	3 [illegible]7	49 [illegible]4	217	1.0[illegible]	224	7.1		
St. Louis, Brownsville & Mexico	[illegible].69	3 [illegible]4	[illegible]	115	1.0[illegible]	117	3.8		
San Antonio, Uvalde & Gulf	3[illegible].71	2 803	[illegible]	164	1.10	180	5.7		
International-Great Northern	1 487.46	2 996	156 736	105	0.99	105	3.5	3 619 265	2.89
Kansas City Southern	1 256.91	3 169	172 677	137	1.04	143	4.3	3 624 322	3.93
Kansas, Oklahoma & Gulf	356.84	3 [illegible]	61 402	172	1.06	182	5.7	2 325 319	7.82
Louisiana & Arkansas	718.63	3 158	161 195	224	0.79	177	7.1	2 598 075	6.83
Louisiana, Arkansas & Texas	245.30	3 [illegible]5	102 539	418	0.64	268	13.8	1 519 927	17.64
Midland Valley	386.61	2 969	35 613	92	1.01	93	3.1	933 [illegible]70	9.93
Missouri & Arkansas	356.86	3 116	123 414	346	0.42	145	11.1	927 [illegible]22	15.64
Missouri-Kansas-Texas Lines	4 096.49	3 149	405 764	99	1.06	105	3.1	3 189 001	3.29
Missouri Pacific	[illegible]	3 [illegible]	1 [illegible]	171	1.08	185	5.5	4 267 1[illegible]	4.[illegible]
Oklahoma City-Ada-Atoka	[illegible]	[illegible]	[illegible]4 [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
St. Louis-San Francisco	[illegible] 49[illegible].44	3 [illegible]4	[illegible]	1[illegible]	[illegible]	14[illegible]	5.[illegible]	[illegible]	[illegible].44
St. Louis, San Fran. & Texas	258.09	3 155	39 314	152	0.95	145	4.8	1 747 41[illegible]	8.[illegible]
St. Louis Southwestern Lines	1 9[illegible].89	3 171	305 150	158	1.11	177	5.[illegible]	3 913 872	4.51
Texas & New Orleans	5 633.80	2 754	748 426	13[illegible]	0.97	129	4.8	3 018 365	4.29
Texas & Pacific	2 477.34	2 920	231 943	94	1.03	97	3.2	4 622 240	2.09
Texas Mexican	205.58	3 168	27 753	135	1.16	156	4.3	927 444	16.84
CANADIAN ROADS:									
Canadian National	27 041	2 925	5 797 181	214	0.80	172	7.3	2 269 450	
Canadian Pacific	20 565	2 804	3 559 081	170	0.86	146	5.9	2 511 850	6.00
Temiskaming & Nor. Ontario	534	2 900	136 679	251	0.72	180	8.8	2 723 409	6.60

Col.3 derived by dividing Col.9 Table A by Col.8 of same table.
Col.4 is total of Cols.2 and 4 of Table A.
Col.5 derived by dividing total of Cols.2 and 4 Table A, by Col.8 of same table.
Col.6 is weighted average of costs shown in Cols.3 and 5 of Table A.

Note: Compiled from annual reports of Class I railways to the Interstate Commerce Commission.

Compiled by
Association of American Railroads
Bureau of Railway Economics
Washington, D.C.

TABLE C

NUMBER AND AGGREGATE COST OF WOODEN CROSS TIE RENEWALS PER MILE OF MAINTAINED TRACK AND RATIO OF WOODEN CROSS TIE RENEWALS TO TOTAL WOODEN CROSS TIES IN MAINTAINED TRACK

Class I roads in the United States and large Canadian roads, by years, and for the average of the five years 1934 to 1938, inclusive

Note: All figures are exclusive of bridge and switch ties.

Road	Number of wooden cross tie renewals per mile of maintained track						Aggregate cost of wooden cross tie renewals per mile of maintained track						Per cent wooden cross tie renewals to all ties in tracks					
	1934	1935	1936	1937	1938	5 year average	1934	1935	1936	1937	1938	5 year average	1934	1935	1936	1937	1938	5 year average
NEW ENGLAND REGION:																		
Bangor & Aroostook	204	190	188	198	190	194	$127	$106	$102	$109	$109	$111	7.1	6.7	6.6	6.9	6.6	6.8
Boston & Maine	118	64	71	103	73	86	139	94	99	155	105	130	4.1	2.2	2.4	[illegible]	[illegible]	2.9
Canadian Nat. Lines in New Eng.	85	92	135	111	130	111	114	137	163	122	139	135	2.8	3.0	4.4	3.6	4.2	3.6
Canadian Pacific lines in Me.,	182	153	148	139	107	146	252	186	181	175	154	140	6.3	[illegible]	5.1	4.8	3.7	5.0
Canadian Pacific (lines in Vt.,	68	53	42	46	55	53	90	66	53	48	70	67	[illegible]	1.5	[illegible]	1.4	1.5	1.5
Central Vermont	193	153	137	113	[illegible]	139	261	213	195	166	150	197	6.3	5.0	4.5	[illegible]	[illegible]	4.6
Maine Central	192	187	219	230	202	206	216	204	254	271	245	238	6.3	[illegible]	7.2	[illegible]	[illegible]	6.8
New York Connecting	257	213	317	226	297	262	411	[illegible]	469	332	453	399	8.0	6.7	9.9	7.1	[illegible]	8.2
New York, New Haven & Hartford	62	71	86	75	70	73	85	93	107	93	90	94	2.2	2.3	2.8	2.6	[illegible]	2.4
Rutland	129	109	[illegible]	74	57	91	134	129	111	94	77	109	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
GREAT LAKES REGION:																		
Ann Arbor	106	106	110	101	90	103	141	142	142	133	127	137	[illegible]	3.6	3.7	[illegible]	[illegible]	[illegible]
Cambria & Indiana	341	257	285	338	342	[illegible]	296	211	277	437	475	339	[illegible]	8.8	10.8	12.9	[illegible]	11.6
Delaware & Hudson	103	106	[illegible]	108	73	97	206	223	199	230	154	202	[illegible]	[illegible]	3.1	[illegible]	2.4	[illegible]
Delaware, Lackawanna & Western	108	92	127	70	57	91	129	128	161	97	95	122	[illegible]	3.2	4.4	[illegible]	2.0	3.1
Detroit & Mackinac	101	132	119	127	156	127	[illegible]	70	[illegible]	72	76	[illegible]	[illegible]	4.4	4.0	[illegible]	[illegible]	4.2
Detroit & Toledo Shore Line	[illegible]	134	129	111	82	108	137	235	224	196	147	188	2.7	4.4	4.2	3.6	[illegible]	[illegible]
Erie (Incl. C&E	104	[illegible]	88	90	82	91	144	131	124	132	124	131	3.6	[illegible]	[illegible]	3.1	2.8	3.1
Grand Trunk Western	[illegible]	153	[illegible]	150	144	152	190	206	223	217	230	213	4.5	4.8	5.1	4.8	4.6	4.8
Lehigh & Hudson River	[illegible]	46	57	91	90	61	40	77	103	184	206	122	0.9	1.5	2.2	[illegible]	[illegible]	2.3
Lehigh & New England	75	[illegible]	64	59	59	65	127	[illegible]	90	[illegible]	[illegible]	97	[illegible]	[illegible]	2.1	[illegible]	[illegible]	[illegible]
Lehigh Valley	56	74	[illegible]	22	46	49	94	100	[illegible]	32	63	[illegible]	2.2	2.5	1.3	[illegible]	1.6	1.7
Monongahela	155	157	148	182	104	[illegible]	270	[illegible]	[illegible]	[illegible]	179	280	5.4	5.4	6.5	6.3	3.6	5.4
Montour	115	103	94	101	88	100	[illegible]	[illegible]	177	222	179	[illegible]	4.1	[illegible]	3.4	3.6	3.2	3.0
New Jersey & New York	82	70	64	65	44	65	100	99	77	[illegible]	67	79	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
New York Central R.R. Co.	70	71	82	97	83	81	102	96	118	[illegible]	125	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
New York, Chicago & St. Louis	94	88	94	111	94	94	151	141	135	167	147	148	2.7	[illegible]	3.0	3.5	[illegible]	3.0
New York, Ontario & Western	69	83	51	55	43	60	82	122	67	72	63	81	[illegible]	[illegible]	1.8	1.9	1.5	2.1
New York, Susquehanna & Western	130	99	92	85	73	96	170	129	111	112	104	125	4.5	3.4	3.1	[illegible]	[illegible]	3.3
Pere Marquette	123	127	142	172	153	143	164	182	214	281	257	[illegible]	4.1	4.2	4.7	5.7	[illegible]	4.8
Pittsburgh & Lake Erie	41	39	51	71	32	45	76	59	102	124	[illegible]	85	1.4	1.0	1.7	[illegible]	1.1	1.5
Pittsburg & Shawmut	260	261	301	348	224	279	241	309	283	476	320	326	9.3	[illegible]	10.8	12.5	8.0	[illegible]
Pittsburgh & West Virginia	187	170	305	318	265	250	186	175	267	524	488	328	6.5	[illegible]	10.6	10.9	9.1	8.6
Pittsburg, Shawmut & Northern	183	174	180	[illegible]	113	161	249	157	164	155	112	167	[illegible]	5.9	[illegible]	[illegible]	[illegible]	5.5
Wabash	130	149	146	151	153	144	190	205	204	229	216	209	4.2	4.5	4.7	4.9	4.9	4.6
CENTRAL EASTERN REGION:																		
Akron, Canton & Youngstown	264	[illegible]	194	173	165	227	333	366	240	226	179	269	[illegible]	[illegible]	6.7	[illegible]	[illegible]	[illegible]
Baltimore & Ohio	81	91	109	118	65	93	132	128	146	168	103	135	2.9	3.2	3.8	4.2	[illegible]	3.3
Bessemer & Lake Erie	241	239	[illegible]	[illegible]	[illegible]	244	501	507	[illegible]	[illegible]	467	[illegible]	7.8	[illegible]	8.4	8.7	6.9	7.9
Central R.R. of New Jersey	33	49	60	62	[illegible]	49	54	[illegible]	98	106	68	81	[illegible]	1.8	2.1	[illegible]	1.4	1.7
Chicago & Eastern Illinois	98	103	79	97	111	97	109	107	91	109	134	110	3.2	[illegible]	2.6	[illegible]	[illegible]	[illegible]
Chicago & Illinois Midland	64	147	99	85	76	94	80	193	151	135	134	139	2.1	4.8	[illegible]	2.7	[illegible]	3.1
Chicago, Indpls. & Louisville	82	97	77	96	183	107	83	101	82	101	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	6.0	[illegible]
Detroit, Toledo & Ironton	142	155	134	130	110	134	172	[illegible]	152	159	143	164	[illegible]	5.4	4.6	[illegible]	3.8	4.6
Elgin, Joliet & Eastern	165	176	211	216	98	173	[illegible]	242	300	331	164	[illegible]	[illegible]	5.7	[illegible]	[illegible]	3.1	[illegible]
Illinois Terminal	73	85	88	96	84	[illegible]	68	88	98	114	75	93	2.7	[illegible]	2.9	[illegible]	2.8	[illegible]
Long Island	64	58	58	65	60	65	103	73	84	131	113	101	[illegible]	2.0	2.0	2.9	2.0	[illegible]
Missouri-Illinois	296	421	354	339	279	344	168	361	260	272	280	272	[illegible]	13.4	[illegible]	10.9	[illegible]	11.0
Pennsylvania R.R.	64	57	79	105	60	73	100	89	114	168	93	113	[illegible]	[illegible]	2.8	3.7	[illegible]	2.6
Penna.-Reading Seashore Lines	56	49	46	59	76	57	75	58	66	123	171	99	2.1	1.8	1.7	2.1	2.8	2.1
Reading Co.	35	36	41	41	28	36	60	63	71	76	48	64	1.3	1.3	1.5	1.5	1.0	1.3
Staten Island Rapid Transit	69	48	45	72	52	57	175	110	89	126	49	110	2.5	1.8	1.7	2.0	1.9	2.1
Western Maryland	219	202	226	194	128	194	260	253	294	267	190	253	7.6	7.0	7.9	6.7	4.5	6.7
Wheeling & Lake Erie	63	221	220	211	90	161	85	277	290	295	122	214	2.1	7.3	7.3	7.0	[illegible]	5.3
POCAHONTAS REGION:																		
Chesapeake & Ohio	94	73	91	66	85	82	104	86	99	75	104	94	3.1	2.4	3.0	2.1	2.8	2.7
Norfolk & Western	90	75	61	42	22	53	102	82	64	45	27	64	2.9	2.4	2.0	1.3	0.7	1.9
Richmond, Fred. & Potomac	344	314	281	305	268	302	260	231	255	422	437	321	12.0	11.0	9.9	10.7	9.4	10.6
Virginian	208	215	220	225	178	209	221	181	236	224	262	225	6.7	6.9	7.1	7.2	5.7	6.7
SOUTHERN REGION:																		
Alabama Great Southern	275	253	217	183	149	215	335	335	278	256	215	284	8.9	8.2	7.0	5.9	4.8	7.0
Atlanta & West Point	151	151	156	196	162	163	225	231	219	201	158	207	5.0	4.9	5.1	6.4	5.3	5.3
Western Ry. of Alabama	120	138	141	165	175	148	173	194	188	169	201	185	4.0	4.5	4.6	5.4	5.8	4.9
Atlanta, Birmingham & Coast	151	156	188	179	151	165	110	106	155	186	148	141	5.2	5.6	6.5	6.2	5.2	5.7
Atlantic Coast Line	145	154	140	112	129	136	114	116	103	98	131	112	5.0	5.3	4.8	3.9	4.4	4.7
Central of Georgia	121	121	126	136	145	130	85	96	104	118	149	110	4.3	4.3	4.5	4.9	4.9	4.6
Charleston & Western Carolina	163	177	172	[illegible]	146	163	[illegible]	166	166	[illegible]	[illegible]	161	[illegible]	6.1	[illegible]	[illegible]	[illegible]	[illegible]
Cincinnati, New Orleans & Tex. Pac.	163	145	133	107	86	128	225	222	208	166	142	[illegible]	5.2	4.7	4.4	4.5	[illegible]	4.1
Clinchfield	314	304	308	312	252	298	272	274	284	307	263	280	10.3	10.0	10.1	10.3	8.3	9.8
Columbus & Greenville	220	271	209	221	203	225	198	196	210	257	203	213	6.9	8.6	6.6	7.0	6.4	7.1
Florida East Coast	135	141	131	193	134	145	102	102	99	143	119	113	4.7	4.9	4.6	6.4	4.7	5.1
Georgia R.R.	133	110	111	143	161	132	143	148	116	180	199	157	4.3	3.6	3.6	4.7	5.3	4.3
Georgia & Florida	266	278	269	266	181	252	136	148	167	179	116	149	9.8	10.3	10.0	9.8	6.7	9.3
Georgia, Southern & Florida	99	79	84	88	77	85	69	60	67	87	80	73	3.2	2.5	2.7	2.8	2.5	2.7
Gulf & Ship Island	171	152	144	174	194	167	78	100	133	175	202	138	5.6	5.0	4.7	5.7	6.3	5.5
Gulf, Mobile & Northern	157	207	201	318	257	228	120	177	173	310	274	211	5.0	6.5	6.3	10.0	8.1	7.2
Illinois Central	135	133	144	142	147	140	122	120	137	144	156	136	4.4	4.4	4.7	4.6	4.8	4.6
Yazoo & Mississippi Valley	123	149	144	152	170	148	102	109	115	142	159	125	4.0	4.9	4.7	5.0	5.6	4.8
Louisville & Nashville	110	107	110	115	113	111	134	131	135	144	152	139	3.8	3.8	3.9	4.0	3.9	3.9
Mississippi Central	155	218	338	376	221	262	148	145	289	378	218	236	4.9	6.9	10.7	11.9	7.0	8.3
Mobile & Ohio	317	314	317	289	299	307	214	205	209	235	234	219	10.0	10.0	10.0	9.1	9.4	9.7
Nashville, Chattanooga & St. Louis	173	140	118	114	109	131	173	144	129	129	149	145	5.9	4.7	4.0	3.9	4.0	4.5
New Orleans & Northeastern	196	159	137	131	116	148	224	207	171	178	165	189	6.3	5.1	4.4	4.2	3.7	4.7
Norfolk Southern	386	362	280	367	279	335	224	206	163	272	192	211	13.6	12.7	9.9	12.0	9.1	11.5
Northern Alabama	364	377	384	393	394	382	301	267	431	486	501	397	11.5	12.1	12.3	12.6	[illegible]	12.2
Seaboard Air Line	215	237	226	204	187	214	171	182	183	189	194	184	7.7	8.2	7.5	6.8	6.2	7.3
Southern Ry.	282	273	259	240	205	252	273	244	256	280	266	264	9.0	8.7	8.3	7.7	6.5	8.0
Tennessee Central	325	288	294	254	200	272	242	295	245	169	143	219	10.4	9.2	9.7	8.4	6.6	8.9

TABLE

NUMBER AND AGGREGATE COST OF WOODEN CROSS TIE RENEWALS PER MILE OF MAINTAINED TRACK AND RATIO OF WOODEN TIE RENEWALS TO TOTAL WOODEN CROSS TIES IN MAINTAINED TRACK

Class I roads in the United States and large Canadian roads, by years, and for the average of the five years 1934 to 1938, inclusive

Note: All figures are exclusive of bridge and switch ties.

Road	Number of wooden cross tie renewals per mile of maintained track						Aggregate cost of wooden cross tie renewals per mile of maintained track						Per cent wooden cross tie renewals to all ties in track					
	1934	1935	1936	1937	1938	5 year average	1934	1935	1936	1937	1938	5 year average	1934	1935	1936	1937	1938	5 year average
NORTHWESTERN REGION.																		
Chicago & North Western	116	123	143	149	154	137	[illegible]	$110	$126	$134	$143	$126	[illegible]	4.1	4.8	[illegible]	4.7	4.5
Chicago Great Western	194	165	151	170	157	169	209	162	185	225	[illegible]	196	6.7	5.7	5.1	[illegible]	[illegible]	5.8
Chicago, Milwaukee, St. Paul & Pac	184	141	212	138	125	180	168	263	[illegible]	135	125	180	6.2	6.1	[illegible]	[illegible]	4.1	6.0
Chicago, St. Paul, Minneapolis & Omaha	164	146	167	189	182	170	143	129	151	178	167	158	5.5	4.9	5.6	6.4	6.1	5.7
Duluth, Missabe & Iron Range	62	52	76	120	63	75	42	71	110	148	82	101	2.1	1.8	[illegible]	[illegible]	[illegible]	[illegible]
Duluth, South Shore & Atlantic	161	203	223	[illegible]	193	[illegible]	[illegible]	99	126	152	118	116	5.6	7.1	7.8	[illegible]	[illegible]	7.2
Duluth, Winnipeg & Pacific	375	369	376	366	[illegible]	344	177	193	223	210	238	208	[illegible]	[illegible]	12.5	10.2	[illegible]	[illegible]
Great Northern	110	104	112	121	106	111	[illegible]	112	126	141	132	125	3.4	3.3	3.6	3.9	3.4	3.5
Green Bay & Western	340	417	441	352	[illegible]	374	[illegible]	[illegible]	391	343	314	316	12.1	14.8	15.3	12.2	11.1	13.1
Lake Superior & Ishpeming	186	198	225	193	168	194	[illegible]	117	136	125	114	119	6.2	7.0	7.5	6.4	5.8	6.5
Minneapolis & St. Louis	104	136	106	199	198	169	95	116	168	195	193	153	5.4	4.5	6.8	[illegible]	6.5	5.6
Minneapolis, St. Paul & S. S. Marie	158	179	179	169	161	169	130	146	162	143	122	141	5.4	6.1	6.1	5.7	5.5	5.8
Northern Pacific	82	91	122	129	125	110	89	94	126	126	144	116	2.8	3.2	[illegible]	4.3	4.4	3.8
Spokane International	313	300	341	370	329	331	[illegible]	123	153	168	150	146	11.1	10.6	12.1	13.1	11.6	[illegible]
Spokane, Portland & Seattle	141	130	166	173	231	170	68	76	120	150	228	128	4.7	4.3	[illegible]	5.7	[illegible]	5.5
CENTRAL WESTERN REGION.																		
Alton R.R.	[illegible]	247	240	233	248	246	293	266	287	290	352	299	8.7	8.2	7.9	7.7	8.2	8.1
Atchison, Topeka & Santa Fe (see note)	97	108	120	125	84	107	105	117	136	143	102	121	3.2	3.6	4.0	4.1	2.8	[illegible]
Chicago, Burlington & Quincy	91	120	135	144	153	130	109	146	170	186	201	162	2.9	3.9	4.5	4.8	4.9	[illegible]
Chicago, Rock Island & Pacific	61	69	101	130	121	96	63	61	[illegible]	119	124	92	[illegible]	2.3	3.4	4.4	4.1	3.2
Chicago, Rock Island & Gulf	[illegible]	73	86	51	[illegible]	78	112	109	123	93	87	105	2.2	2.4	2.8	2.6	2.7	[illegible]
Colorado & Southern	144	133	123	86	78	113	123	102	100	89	92	103	4.7	4.4	4.1	2.9	2.6	3.7
Denver & Rio Grande Western	167	134	151	137	81	134	168	129	147	145	93	136	5.4	4.3	4.8	4.4	2.6	4.3
Denver & Salt Lake	191	315	468	395	42	282	154	234	589	502	60	318	6.2	10.3	15.3	[illegible]	1.4	9.2
Fort Worth & Denver City	35	46	64	73	94	[illegible]	36	49	67	78	106	67	1.1	1.5	2.1	2.4	3.1	[illegible]
Nevada Northern	129	132	131	140	162	139	96	108	102	112	143	112	4.5	[illegible]	4.0	4.5	5.0	4.0
Northwestern Pacific	136	73	64	123	104	101	73	44	43	99	84	69	4.6	2.5	2.2	4.4	3.6	3.5
Southern Pacific Co.- Pac. Lines	65	62	78	92	99	79	66	67	91	107	114	89	2.2	2.1	2.6	3.1	3.3	2.7
Toledo, Peoria & Western	256	230	278	399	356	304	309	298	372	568	505	410	8.1	7.2	8.8	12.6	11.2	9.6
Union Pacific (see note)	126	139	159	178	153	15	[illegible]	135	166	183	170	166	4.5	4.9	[illegible]	6.3	5.5	6.1
Utah Ry.	166	272	259	155	97	190	174	415	403	228	153	279	6.4	13.5	10.0	5.8	3.6	7.3
Western Pacific	274	295	361	[illegible]	243	313	172	192	237	361	282	249	9.4	10.1	12.2	13.2	8.2	10.6
SOUTHWESTERN REGION:																		
Burlington-Rock Island	56	54	76	69	54	63	38	41	59	41	54	47	1.8	1.7	2.4	2.2	1.9	2.0
Gulf Coast Lines.																		
Beaumont, Sour Lake & Western	11	92	77	[illegible]	[illegible]	99	[illegible]	86	83	[illegible]	111	102	3.7	3.1	[illegible]	3.7	3.5	[illegible]
New Orleans, Texas & Mexico	[illegible]	[illegible]	119	175	[illegible]	144	[illegible]	102	124	190	224	149	3.4	3.5	3.9	5.7	7.1	4.7
St. Louis, Brownsville & Mexico	45	66	81	113	115	[illegible]	41	58	82	[illegible]	117	84	1.5	2.2	2.7	[illegible]	3.8	2.8
San Antonio, Uvalde & Gulf	[illegible]	96	[illegible]	125	164	[illegible]	76	[illegible]	110	142	180	120	2.7	3.3	3.1	4.3	5.7	3.8
International-Great Northern	[illegible]	115	[illegible]	101	105	108	96	[illegible]	103	102	105	102	3.7	3.9	3.5	3.4	3.5	3.6
Kansas City Southern (see note)	109	102	117	132	137	119	99	[illegible]	121	137	143	120	3.4	[illegible]	3.7	4.2	4.3	3.8
Kansas, Oklahoma & Gulf	[illegible]	[illegible]	233	205	172	[illegible]	[illegible]	237	245	206	182	[illegible]	6.5	7.6	7.8	6.8	5.7	6.9
Louisiana & Arkansas	251	[illegible]	215	197	224	223	157	137	137	145	177	151	7.9	7.3	6.8	6.2	7.1	7.1
Louisiana, Arkansas & Texas	354	[illegible]	[illegible]	304	[illegible]	[illegible]	[illegible]	[illegible]	297	187	268	227	11.7	[illegible]	15.0	[illegible]	13.8	12.8
Midland Valley	97	56	115	115	[illegible]	[illegible]	96	[illegible]	[illegible]	119	93	103	3.0	[illegible]	3.6	3.5	3.1	3.3
Missouri & Arkansas	327	227	405	430	346	347	154	[illegible]	161	191	145	150	10.5	7.3	13.0	[illegible]	11.1	11.1
Missouri-Kansas-Texas Lines	127	125	110	[illegible]	99	[illegible]	138	127	107	116	105	119	[illegible]	[illegible]	3.5	3.9	3.1	3.7
Missouri Pacific	169	218	214	195	171	193	[illegible]	193	[illegible]	[illegible]	185	189	[illegible]	[illegible]	6.9	6.3	5.5	6.2
Oklahoma City-Ada-Atoka	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	187	[illegible]	[illegible]	[illegible]	123	147	113	3.8	4.1	7.0	7.8	8.1	6.2
St. Louis-San Francisco	[illegible]	215	199	206	180	[illegible]	198	[illegible]	206	209	192	205	6.4	6.8	6.3	6.5	5.7	[illegible]
St. Louis, San Fran. & Texas	427	[illegible]	266	165	[illegible]	278	385	[illegible]	[illegible]	142	145	263	13.5	[illegible]	8.4	5.2	4.8	8.8
St. Louis Southwestern Lines	72	68	179	190	158	133	56	77	184	205	177	146	2.3	[illegible]	5.7	6.0	5.0	4.2
Texas & New Orleans	121	66	122	132	133	115	85	49	[illegible]	122	129	97	4.5	2.4	4.5	4.8	4.8	4.2
Texas & Pacific	78	[illegible]	[illegible]	88	94	91	64	74	95	88	97	84	2.7	[illegible]	3.5	3.0	3.2	3.1
Texas Mexican	152	197	241	266	135	198	161	[illegible]	256	306	156	216	[illegible]	6.8	6.4	9.2	4.5	6.8
CANADIAN ROADS																		
Canadian National (see note)	198	221	242	213	214	218	188	180	169	174	172	180	6.9	7.7	6.5	7.4	7.3	7.7
Canadian Pacific (see note)	166	161	160	164	170	164	135	135	142	143	146	139	5.9	5.7	5.7	5.8	5.9	5.8
Temiskaming & Nor. Ontario	245	228	209	207	251	228	170	156	151	138	[illegible]	[illegible]	8.6	8.0	7.4	7.2	8.8	8.0

Note. Statement applies to Class I roads and includes consolidated data for Class I roads merged during the period 1934 to 1938, as follows.
Atchison, Topeka & Santa Fe - includes Panhandle & Santa Fe, Gulf, Colorado & Santa Fe, and Fort Worth & Rio Grande.
Kansas City Southern - includes Texarkana & Fort Smith.
Union Pacific - includes Los Angeles & Salt Lake, Oregon-Washington R. R. & Nav. Co., Oregon Short Line; and St. Joseph & Grand Island.
Canadian National Rys. - excludes lines in New England; Grand Trunk Western; Central Vermont; and Duluth, Winnipeg & Pacific.
Canadian Pacific - excludes Dominion Atlantic and Quebec Central.

Compiled by
Association of American Railroads
Bureau of Railway Economics
Washington, D.C.

Appendix D

(5) Proper Seasoning of Oak Ties with Special Reference to Those Grown in Southern Lowlands

Collaborating with Committee 17—Wood Preservation

C. D. Turley (chairman, subcommittee), R. S. Belcher, H. R. Duncan, C. F. Ford, B. D. Howe, C. S. Kirkpatrick.

During the past five years test stacks of ties were under observation in the seasoning yards of the A. T. & S. F., C. R. I. & P., Erie, I. C., L. & N. and M. P. railroads. The results proved so conflicting and contradictory as to make clear that only very extensive tests, involving many thousands of ties, stacked in various ways in numerous places, and subjected to frequent detail measurements would supply data from which definite conclusions could be drawn. Since such extensive experimentation would involve considerable expense, it is not deemed advisable for this committee to attempt any further tests. The railroads with a special interest in the splitting of certain species of oak from certain localities may find it feasible to develop, in their routine seasoning procedure, ways and means for observing the behavior of such woods.

It is recommended that the subject be discontinued on account of its intangibility at moderate expense and because it is a localized phase of the broader Subject 7—The cause and control of splitting in railroad ties.

Presented as information with the recommendation that the subject be discontinued.

Appendix E

(6) Investigate and Report on the Dimensions of Ties and Bring Up to Date the Information Presented in the 1924 and 1932 Proceedings

W. J. Burton (chairman, subcommittee), W. C. Bolin, W. H. Brameld, H. F. Brown, S. B. Clement, R. L. Cook, C. S. Kirkpatrick, D. O. Lyle, A. F. Maischaider, W. D. Simpson, Sverre Thorvaldson.

1. 1924 Proceedings

The 1924 report contains the results of a questionnaire as to tie sizes then in use and the following conclusions:

1. The size of ties most widely used under heavy traffic (main track in main lines) has increased since 1905 from 6 by 8 in. by 8 ft. to 7 by 9 in. by 8 ft. 6 in.

2. Owing to many variables involved, including strength of timber in its average condition in track, condition of road bed, etc., it is not possible to calculate a design for a tie in the sense that a bridge member is designed.

3. For heavy traffic, ties should have a minimum thickness of 7 in., a maximum width of 12 in. and a length of at least 8½ ft. or possibly 9 ft.

4. A space of 10 in. between tops of ties allows sufficient room for tamping; the maximum of bearing area on the ballast may be secured by use of the wider and longer ties laid with this spacing.

TABLE 1

SIZES OF CROSS TIES PURCHASED

Road	Approximate Percentage of Each Size Purchased															References
	8-foot ties Size No.					8½-foot ties Size No.					9-foot ties Size No.					
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	
New England Region																
Bangor & Aroostook	35	30	35													
Boston & Maine	4	7	5	1	2	19	30	23	3	6						
C. N. R. in New Eng.																Ref. 1
C. P. R. in Maine			63		37											Ref. 2
C. P. R. in Vermont			63		37											Ref. 2
Central Vermont																Ref. 1
Maine Central	10	10	20	5	4			5	10	36						
New York Connecting							20			80						Ref. 2
N. Y. N. H. & H.							20			80						
Rutland	14	14	72													
Great Lakes Region																
Ann Arbor	5	23	31						6	35						Ref. 2
Cambria & Indiana																Ref. 3
Delaware & Hudson								25	25	50						
D. L. & W.								17	33	50						
Detroit & Mackinac	38		62													
D. & T. S. L.			48	17	35											
Erie						8	15	18	19	40						
Grand Trunk Western																Ref. 1
Lehigh & Hudson River																Ref. 3
Lehigh & New England						1	1	25	20	53						
Lehigh Valley							15	25	25	35						
Monongahela						15	26	45	3	11						
Montour									21	79						
New Jersey & N. Y.						8	15	18	19	40						Ref. 2
New York Central						4	9	17	21	49						
N. Y. C. & St. L.							20	34	11	35						
N. Y. Ontario & W.			100													
N. Y. S. & W.						8	15	18	19	40						Ref. 2
Pere Marquette	10	20	23					12	12	23						
P. & L. E.								8	26	66						
Pittsburg & Shawmut						10	10	12	34	34						
Pittsburgh & W. Va.																Ref. 3
P. S. & N.						4	19	23	20	34						
Wabash	5	23	31						6	35						
Central Eastern Region																
A. C. & Y.					1	8	4	9	4	74						
Baltimore & Ohio						6	12	22	16	44						
B. & L. E.								9	17	74						
C. R. R. of N. J.						12	17	25	14	32						
C. & E. I.	5	35	60													
Chicago & Ill. Midland			70							30						
C. I. & L. (Monon)		20	40	40												
D. T. & I.						5	16	28	21	30						
E. J. & E.		53	47													
Illinois Terminal																Ref. 3
Long Island (Penna.)						12	14	18	19	37						Ref. 2
Missouri-Illinois	26	32	42													
Pennsylvania						12	14	18	19	37						
Penna.-Reading Sea. S.						12	14	18	19	37						Ref. 2
Reading Co.						10	15	30	15	30						
Staten Island R. T.						10	11	21		58						
Western Maryland						6	10	22	21	41						
W. & L. E.		1	2	1	2	3	12	23	18	38						
Pocahonatas Region																
Chesapeake & Ohio							14	20	22	44						
Norfolk & Western						5	10	15	19	51						
R. F. & P.						9	25	20	18	28						
Virginian						8	9	22	19	42						
Southern Region																
Alabama Gt. Southern			9					13	14	64						Ref. 2
Atlanta & West Point								10	20	70						
Western Ry. of Ala.								10	20	70						
A. B. & C.								16	16	68						
A. C. L.								8	12	80						

Table 1 (Continued)

Sizes of Cross Ties Purchased

Road	*Approximate Percentage of Each Size Purchased*															*References*
	8-foot ties Size No.					*8½-foot ties Size No.*					*9-foot ties Size No.*					
	1	*2*	*3*	*4*	*5*	*1*	*2*	*3*	*4*	*5*	*1*	*2*	*3*	*4*	*5*	
Southern Region																
Central of Georgia			13	16	71											
Charleston & West. Car.								8	12	80						
C. N. O. & T. P.			9					13	14	64						Ref. 2
Clinchfield								21	23	56						
Cols. & Greenville								10	20	70						
Florida East Coast								5	15	80						
Georgia R. R.								10	20	70						
Georgia & Florida								50	40	10						
Georgia, Southern & Fla.			9					13	14	64						Ref. 2
Gulf & Ship Island		9	80					2	1	8						Ref. 2
G. M. & N.							5	30	35	30						
Illinois Central		9	80					2	1	8						
Y. & M. V.		9	80					2	1	8						Ref. 2
L. & N.						8	5	19	20	48						
Mississippi Central								100								
Mobile & Ohio						1	1	16	9	73						
N. C. & St. L.								25	14	61						
New Orleans & N. E.			9					13	14	64						Ref. 2
Norfolk Southern							10	15	15	60						
Northern Alabama			9					13	14	64						Ref. 2
Seaboard Air Line								14	22	64						
Southern Ry.			9					13	14	64						Ref. 2
Tennessee Central						1	6	21	24	48						
Northwestern Region																
C. & N. W.	20	17	37	26												
C. G. W.																Ref. 3
C. M. St. P. & P.	5	10	41	41					3							
C. St. P. M. & O.	15	18	27	30												Ref. 6—10%
D. M. & I. R.																Ref. 3
D. S. S. & A.																Ref. 3
D. W. & P.																Ref. 1
Great Northern	2	2	5	7				13	12	59						
G. B. & W.	9	46	41	4												
L. S. & I.	32	16	15	12	12											Ref. 6—13%
M. & St. L.	40	27	23	10												
M. St. P. & S. S. M.	26	15	13	15												Ref. 6—31%
Northern Pacific	7	4	18	33						38						
Spokane Internat.	4		44	1	51											
S. P. & S.				73						27						
Central Western Region																
Alton	2	7	17	11	28		1	7	6	21						
A. T. & S. F.	5	22												36	37	Ref. 5
C. B. & Q.	2	14	28	16	3				11	26						
C. R. I. & P.	2	6	26	10	28				6	22						
C. R. I. & G.	2	6	26	10	28				6	22						
C. & S.	15	16	34	35												
D. & R. G. W.	5	8	43	22	22											Ref. 7
D. & S. L.																Ref. 3
F. W. & D. C.	4	11	30	55												
Nevada Northern				100												
Northwestern Pac.				100												
Southern Pacific			21	19	60											
T. P. & W.			100													
Union Pacific																Ref. 4
Utah Ry.				33	53										14	
Western Pacific				26	74											
Southwestern Region																
Burlington—Rock Island	4	15	52	29												
Gulf Coast Lines		7	35	24	34											
I. G. N.		7	35	24	34											
K. C. S.		8	36	14	42											
K. O. & G.																Ref. 3
Louisiana & Arkansas			15	35	50											
Louisiana, Ark. & Texas			15	35	50											Ref. 2
Midland Valley																Ref. 3
Missouri & Arkansas			74										26			

TABLE 1 (Continued)

SIZES OF CROSS TIES PURCHASED

Road	*Approximate Percentage of Each Size Purchased*															*References*
	8-foot ties Size No.					*8½-foot ties Size No.*					*9-foot ties Size No.*					
	1	*2*	*3*	*4*	*5*	*1*	*2*	*3*	*4*	*5*	*1*	*2*	*3*	*4*	*5*	
Southwestern Region																
M. K. & T.	1	6	32	18	43											
M. P.	3	12	26	19	40											
Okla. City, Ada, Atoka																Ref. 3
St. L.—S. F.	3	14	39	9	27											Ref. 6— 8%
St. L.—S. F. of Texas	3	14	39	9	27											Ref. 2 & 6–8%
St. L. S. W.		3	27	22	48											
T. & N. O.		6	19	40	35											
Texas & Pacific		8	32	26	34											
Texas Mexican																Ref. 3
Canadian Roads																
C. N. R.																Ref. 4
C. P. R.			63		37											
Temis. & Nor. Ont.	2	20	37	20	21											

Ref. 1—This railroad is a subsidiary of Canadian National Railways. The latter uses a non-standard specification which does not permit of size comparison.

Ref. 2—This is a subsidiary railroad. The percentages shown are those reported by the parent railroad.

Ref. 3—No report received.

Ref. 4—This railroad uses a non-standard specification which does not permit of size comparison.

Ref. 5—Sizes 4 and 5 purchased as Size 4. Estimated proportions of the two sizes shown.

Ref. 6—This road purchases Size 0 (6 in. thick, 5 in. face) or "serviceable rejects". The percentage of this size or class is shown.

Ref. 7—This road purchased narrow-gage ties (6 ft.) to the extent of 21 percent of the ties shown as 8 feet.

TABLE 2

PERCENTAGES OF TIE LENGTHS AND SIZES BY REGIONS, WEIGHTED ACCORDING TO TOTAL INSERTIONS IN 1938

Region	*Total Ties Applied (a)*	*Sizes*					*Lengths—Fee*		
		1	*2*	*3*	*4*	*5*	*8*	*8½*	*9*
New England	999,415	13	22	23	5	37	39	61	
Great Lakes	4,078,388	5	13	24	17	41	15	85	
Cent. Eastern	3,173,751	9	16	24	17	34	15	85	
Pocahontas	825,243	3	14	20	20	43		100	
Southern	7,872,629	1	3	30	14	52	24	76	
Northwestern	7,664,167	16	11	28	29	16	81	19	
Cent. Western	7,557,215	3	11	20	26	40	75(b)	12	13
Southwestern	5,405,203	3	9	31	20	37	99		1
Canadian	3,695,760		1	62	1	36	100(c)		
Total Ties	41,271,771								

(a) Total ties applied by railroads replying to questionnaire, except Canadian National and Union Pacific, which used non-standard ties.

(b) Including Union Pacific, which used 1,969,781 eight-foot ties.

(c) Including Canadian National which used 5,797,181 eight-foot ties.

2. 1932 Proceedings

The 1932 report is on the "economics of use of 8½-ft. and 9-ft. ties as compared with 8-ft. ties." It presents the information obtained from a questionnaire and shows the lengths of crossties in use on 38 railroads. With only four exceptions, all roads in the Eastern, Southern and Pocahontas groups were using 8½-ft. ties, while all of the roads of the Western group, except two, were using 8-ft. ties.

3. 1939 Proceedings

The 1939 report of the committee contains an analysis of the requirements and conditions as to tie length and the following conclusions:

> It is concluded . . . that an increase in supporting power of the roadway may be obtained by an increase in the length of ties at less expense than by other means.
>
> It is concluded that, considering the additional tie cost, 8½-ft. ties are a better buy than 8-ft. ties and will give added support out of proportion to the added tie cost.

4. Present Practice

In order to obtain present practice as to tie sizes and lengths a questionnaire was sent to each railroad reported in Col. 1 of Table A, of the committee's yearly report on crossties laid in replacement (see Bulletin 411, page 79), asking for the approximate percentages of crosstie sizes and lengths purchased, disregarding any tolerances. The returns generally represent 1938 purchases. The replies are tabulated in Table 1 of this report.

In order to determine weighted averages, the percentages as given in Table 1 were applied to the total 1938 tie insertions, as reported in Col. 7 of Table A (see Bulletin 411, as above). While there is some discrepancy in applying percentages purchased in 1938 to totals inserted in that year, it is the thought that such discrepancy is relatively unimportant for the purposes of this report, particularly considering the fact that percentages of sizes usually do not vary greatly from year to year. The results obtained as above are given in Table 2.

5. Discussion

A trend towards the larger ties is indicated when Table 2 is compared with the 1924 tabulation.

A study of Tables 1 and 2 indicates exceptions to the general regional choice of length. For example, in the Southern region the 8½-ft. length is used almost universally by roads of both very light and very heavy traffic, while in the Southwestern region the 8-ft. tie is used by all classes of roads. These comparisons point to the fact that at least as between 8-ft. and 8½-ft. ties, there is little difference in cost, once the regional custom or standard has become established. As the advantages of greater length do not stop with 8½-ft. ties, the question may well be asked why 9 ft. should not be adopted as standard, at least for heavy traffic. One important railroad (the Santa Fe) located in 8-ft. territory, has recently adopted 9-ft. ties for about three-fourths of its requirements. It is believed that this will result in ultimate economy as well as in stronger track.

This report is submitted as information.

Appendix F

(7) Cause and Control of Splitting in Railroad Ties

R. E. Butler (chairman, subcommittee), R. S. Belcher, H. F. Brown, H. R. Duncan, W. C. Bolin, F. G. Campbell, W. E. Gardner, W. H. Brameld, S. B. Clement, W. D. Simpson, C. D. Turley, A. W. White.

A split is defined as a lengthwise separation of the wood extending from one surface through the tie to the opposite surface or to an adjoining surface. Splits are recognized by railroads as major reasons for renewals, especially since preservative treatment has practically eliminated decay, and warrant careful consideration of the various procedures followed in efforts to minimize them.

No scientific study of tie shrinkage has come to the attention of the committee. Consideration has been given to the conclusions of investigations of the effects of drying pieces smaller in cross section than ties, and it is assumed that in general ties behave as does lumber with similar characteristics.

Why and How Does Wood Shrink?

Moisture in wood is commonly called "sap", but for practical drying purposes, it may be considered as merely water. In green wood, water is held (1) in bulk (free) within cell cavities, (2) in the cell walls. Sapwood contains more "free" water than does heartwood. During any year, variation in the amount of moisture contained by green wood is slight. Species and place of growth have an important bearing on the moisture in the living tree.

Shrinkage of wood takes place only in conjunction with loss of moisture. It does not start until the cells have given up their free water and their walls have begun to lose moisture. The condition in which the cell cavities are entirely empty, with the cell walls still saturated, is known as the "fiber-saturation point". The moisture content at this point ranges between 20 and 35 percent, the percentage varying with the species and also within the same species. All the sections of drying wood do not reach the fiber-saturation point simultaneously; actually the cells near the surface dry below the fiber-saturation point before those in the interior reach it. Thus, though the average moisture content of the whole piece may be above the fiber-saturation point, the outer portion shrinks while the inner does not, and the resistance of the moist interior to the compression of the shrinking dry outer portion causes checks and splits in the latter.

Moisture from the interior of a piece of wood comes to the surface either as a vapor moving along the capillary channels in the wood after evaporation inside the piece, or as a liquid moving through these channels or through the cell walls. On account of the nature of wood structure, the ends lose moisture more rapidly than the sides, and the sides more rapidly than the interior.

Wood shrinks most in the direction of the annual rings (tangentially), about one-half as much across the rings (radially), and very little, as a rule, along the grain (longitudinally). There is no direct relation between the initial moisture content of green wood and its shrinkage as it dries, since shrinkage does not begin in a piece of wood until the fiber-saturation point is reached, from which point the shrinkage in drying is practically in proportion to the moisture lost.

When and Where Do Ties Split?

When a tie will split cannot be determined, and splitting may occur even after a tie has been in track. However, most splits occur during the summer, when the excessive heat causes extra-rapid seasoning.

While most splits start at the ends of ties, some develop from deep checks along a face or edge in ties that have their pith near a surface. Splits usually follow radial lines—both vertically and diagonally through the pith, with the majority extending from top to bottom, which is the shortest distance through the tie, and therefore the line of least resistance to splitting stresses. Round ties split to a greater extent than rectangular ties, due to the additional sapwood on the sides of the former.

How Do Splits Affect the Service?

Any split is harmful and should be controlled before it materially lessens the serviceability of the tie. Splits that occur after treatment expose untreated wood to the entrance of fungi, and the life of the tie is materially shortened by the resulting decay. Splits reduce the bearing area, submitting the severed sections to greater cutting action by the plate or rail. A split tie cannot be properly tamped and the holding power of the spike is reduced.

What Procedure Should Be Followed to Minimize the Splitting of Ties?

Visits made by the committee to numerous seasoning yards of wood-preserving plants during the past fifteen years have provided extended knowledge of the methods in use to prevent splitting of ties. The primary conclusion from the observations made is that, while railroads agree that the loss resulting from splitting should be controlled, they differ in their opinions as to the proper procedure.

The first step in the reduction of this loss is to control the rate of drying. If it were feasible to season a tie so that there would be uniform loss of moisture through the entire tie, shrinkage stresses would be eliminated, which would prevent splits. The cost of kiln-drying so large a cross-section makes that process impracticable.

In the air-seasoning of ties the important factors are temperature and humidity of the atmosphere at the surface of the wood, and proper circulation of air is of extreme importance in maintaining and modifying such temperature and humidity.

Since the circulation of air controls the rate at which the evaporated moisture will be carried away, and the direction, location and width of the intervals between stacks of seasoning ties affect air currents, the method of stacking ties is the controlling factor in providing proper circulation.

Horizontal circulation near the bottom of tie stacks and beneath them is necessary for the vertical circulation of air, which is of utmost importance. Horizontal circulation of air can be regulated to some extent by variation in the yard layout.

As the green ties dry, heat is absorbed, and the air thus becoming cooler and heavier, descends toward the bottom of the stack. Methods of stack construction should therefore be designed to aid this natural movement, permitting, as far as possible, an unobstructed and continuous flow of air. Care must be taken to prevent this vertical flow of air from stagnating in the lower portion of the stack.

Metal devices to hold the wood in place have been quite generally adopted by railroads in seeking a solution of the tie splitting problem. Most of these anti-splitting irons are of the same type, differing only in shape; but the methods of their application vary. Some railroads apply two irons to each end of all hardwood ties (except gum) as they are stacked; others double-iron only main line ties and single-iron side track ties. A second method is to single-iron all ties on arrival at the plant and later apply a second iron to each end. Some railroads use a so-called "selective" system, i.e., they iron only such ties as show indication of splitting at the time of stacking and then make periodical inspections to apply additional irons as the condition of the ties indicates the need. Other railroads iron according to the need apparent on the arrival of the ties, but do no further ironing until ties are trammed for treatment, when all ties which are split or show indication of splitting are ironed. Some railroads do not apply irons until the ties are to be treated and then only to those which seem to need them. Badly-split ties are squeezed in various ways and their parts then fastened by bands, bolts, dowels or several irons. The point that stands out in all of the methods of ironing observed is the necessity for proper application of the anti-splitting device. To be effective, irons must be applied by intelligent labor capable of judging the splitting probabilities in each case.

Loss from badly split ties is minimized where it is possible to select timber that has only slight tendency to split. There is reason for assuming that certain species of oak, grown under certain conditions, split more than other species from other localities.

The above sketchy review of the split-tie problem is presented as information regarding the progress in the study of the subject.

Report of Special Committee on Stresses in Railroad Track

A. N. Talbot, *Chairman,*
C. B. Bronson
W. J. Burton
W. C. Cushing*
Robert Faries
C. W. Gennet, Jr.
F. M. Graham
H. E. Hale
F. S. Hewes
G. W. Kittredge
P. M. LaBach
F. R. Layng
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G. M. Magee
John V. Neubert
W. H. Penfield
W. M. Dawley, *Vice-Chairman,*
G. J. Ray
Albert Reichmann
H. R. Safford
F. E. Turneaure
J. E. Willoughby
Louis Yager
Committee.

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* Died January 12, 1940.

To the American Railway Engineering Association:

The Special Committee on Stresses in Railroad Track, co-operating with the committee of the American Society of Civil Engineers and with the Association of American Railroads, presents the following report of progress:

During the past year the staff of the committee has continued in the work of analyzing and correlating the accumulation of field data and preparing a report for publication. Excellent progress has been made. considering the difficulties and intricacies of the subject. It is planned to have a progress report of the results ready for printing during the summer.

A discussion presented before the last convention by the chairman is given in the last Proceedings, (Volume 40, 1939, page 641). This discussion embraced preliminary reports on the magnitude of the bending moments developed in rail and rail joints as related to type of joint bar and speed of locomotive. Observations were also given on the welded track of the Delaware & Hudson Railroad and the Bessemer & Lake Erie Railroad with reference to stresses developed in rail by reason of changes in temperature. The effective anchorage developed at different distances from the two ends of the welded stretches was shown and the stresses in the unchanging length throughout the long intermediate portion were recorded. Some of the early results found in the operation of the rolling-load testing machine with rail joints tested under different conditions were reported. Remarks were also made relating to failures of joint bars. A resumé of observations and indications found in the service tests of various types of joint bars was given.

Field Tests

The principal field tests made during 1939 were concerned with the possible slipping and spinning of locomotive drivers at high speeds. The committee took advantage of opportunities during the spring and summer to co-operate with the Test department of the Pennsylvania Railroad in planning and conducting an extensive series of tests for obtaining information on various factors influencing action of the locomotive under slipping conditions. The tests were conducted on the track of the Pennsylvania Railroad near Dover, Del. Eight types of locomotives (one having four variations of counterbalance) were used in the tests at various slipping and spinning speeds. Electric strain and movement gages were used on both track and locomotives. The records taken included stresses and depressions at several track locations, stresses in the locomotive side rods, and movements of some of the driving wheels with respect to the frame. Four six-element oscillographs recorded the indications of the various gages. Two of these oscillographs were in a car behind the locomotive and two in the test house beside the

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track. High speed moving pictures were taken of the main driving wheel by a camera mounted on the locomotive. Tests were also made by means of a mechanical oscillator mounted on the main pin of a stationary locomotive and rotated by a gasoline engine at various speeds to produce oscillating vertical forces on the track and the locomotive. The track data made available to the committee in the various tests are being reduced and will be studied as information on the problem.

Service Tests of Joint Bars

In co-operation with Subcommittee 7 on Service Tests of Various Types of Joint Bars of Committee 4—Rail, observational tests have been continued on the 12 half-mile stretches of track on the Pennsylvania Railroad and the 9 mile stretches on the Atchison, Topeka & Santa Fe Railway. As noted in the report of the Committee on Rail, all the various classes of measurements and observations have been continued on the various types of joint bars on the test stretches of the two railroads, and the number of joints given detailed measurement has been increased considerably.

Laboratory Tests

During the year various laboratory tests have been made. Of particular interest and importance are the results of the tests of rail joints made with the rolling-load testing machine in continuous operation throughout the year. The data of the tests, supplemented by information from fatigue test specimens, are bringing information that should be of value in relation to a number of elements entering into the rail joint problem.

Testing Equipment

A thorough study and survey of electrical strain measuring equipment and its design were made during the year and orders placed for such gages, bridge circuits, amplifiers, and auxiliary apparatus as will be complementary to the six-element oscillograph purchased last year. This equipment, though as yet limited in number of units available, will be helpful for extending the scope and value of the work of the committee. With the equipment available it will also be possible to work on the improvement and modification of the present equipment and the development of new methods for recording small strains and movements with better accuracy and less complicated apparatus.

During the year the staff has from time to time given assistance and advice to railroads and allied organizations on special problems within the scope of the committee's experience and knowledge.

It is planned to continue the work along the lines of the general program assigned.

THE SPECIAL COMMITTEE ON STRESSES IN RAILROAD TRACK,
A. N. TALBOT, *Chairman.*

Report on Stresses in Railroad Track*

An Address by A. N. Talbot

Chairman of the Committee on Stresses in Railroad Track
Professor Emeritus, University of Illinois

This opportunity is taken to note the loss of a valued member of the Committee on Stresses in Railroad Track, Mr. William Channing Cushing, retired engineer of standards of the Pennsylvania Railroad, who died January 11, 1940. From the formation of the committee in 1914 to the time of his retirement from railroad service in 1932 Mr. Cushing made important contributions to the work of the committee. His experience and ability added much to its initial planning and to the later discussions and interpretation of data.

A brief report of the work of the Special Committee on Stresses in Railroad Track during 1939 appears on page 657. This embraces a brief outline of the field tests conducted in the summer of 1939 on the Pennsylvania Railroad at Dover, Del. The purpose of these tests was to obtain quantitative information on the action of various types of locomotives with the driving wheels slipping and spinning and also the action of a locomotive having a mechanical oscillator attached to the main driving wheels. The results of these tests will be reported at some later time. Discussion relating to five other topics will now be reported.

Service Tests of Joint Bars

Observations and tests on the various types of rail joints installed in the test stretches of track on the Atchison, Topeka & Santa Fe Railway and the Pennsylvania Railroad have been continued, as described in the report of Subcommittee 7 presented by Mr. Ray McBrian (see Appendix I of the report of the Committee on Rail, beginning on page 632). At the request of Subcommittee 7 a few detailed observations from the inspections made by members of the staff of the Committee on Stresses in Railroad Track will be given here.

As an aid in judging the present surface conditions of the rail joints due to such matters as fit of bar to rail and relative straightness of bar, and to keep tab on wear and other changes that will result from service, measurements of the profile along the rail surface at and near the joint are being made from time to time. What may be called the joint camber for a chord length of 34½ in. on the running surface of the rail was taken from these profiles. In Figs. 1 and 2, two points are plotted for each joint giving the joint camber at ½ in. from each rail end for a chord of 34½ in. Observations at three dates are recorded.

If a plotted point is above the zero line of the diagram the rail end is higher than the surface 17 inches away; if below, it is lower. The joint camber depends of course upon the camber of the bars themselves and other matters like wear, batter and flow. The left point of a pair (connected together) represents the leaving end of a rail, the right point the receiving end of the adjoining rail. In Fig. 1, each point represents the average joint camber in 30 joints for the nine one-mile stretches (60 joints on each stretch) on the Santa Fe for 1937, 1938 and 1939. The upper portion of the figures gives the results for the controlled-cooled non-end-hardened north rail, and the lower portion for the Brunorized and end-hardened south rail. For the north rail, there has been a decrease in joint camber (lowering of rail ends) on all the stretches, averaging 0.01 in. from 1937 to 1939. For the end-hardened south rail the decrease in joint camber has

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* This address, presented on March 13, 1940, supplements the report of the Committee on Stresses in Railroad Track appearing on page 657.

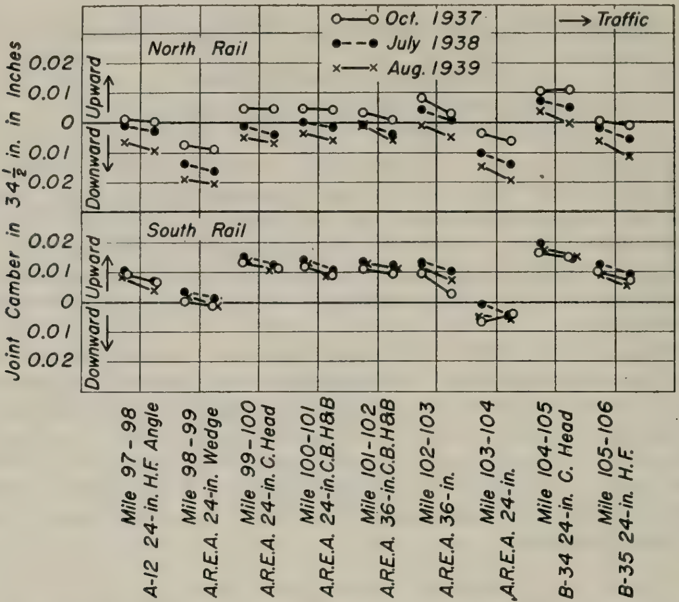

Fig. 1. Joint Camber in 34½ in. at Leaving and Receiving Rail Ends for 60 Joints in Each Test Stretch on A.T. & S.F. Ry. in 1937, 1938 and 1939.

been small, perhaps 5 percent as much as in the north rail, doubtless due to the end hardening. For this south rail the difference in level of the leaving end and the receiving end, due to batter, etc., is not as large as for the north rail as is indicated by the smaller slope of the lines connecting the two points. A frequent reversal of traffic in the train operation over this track doubtless has minimized camber differences at the two rail ends.

Fig. 2 gives corresponding values of joint camber for 60 joints on each of the 12 half-mile stretches on the Pennsylvania in 1937, 1938 and 1939. A feature of the results for the non-end-hardened north rail is that the leaving rail generally shows almost no change in joint camber through the two years, while the change at the receiving end averages 0.008 in. and the inclination of the connecting line has increased in the two years. The field end-hardened south rail shows a somewhat similar increase in slope of the connecting line, and the position of the leaving end has become relatively higher. There is some variation in the indication of batter in the various stretches. In several ways the action of the Evertite joints differs from that named above.

Changes in the position of the bars laterally have also been measured. On the Santa Fe measurements of out-to-out distance of bars near their ends and at mid-length for the top and the bottom show that since 1937 the bars have moved inward toward each other a distance averaging all the way from 0.007 to 0.078 in. in the 9 stretches of 60 measured joints in each stretch. The movement is fairly uniform along the length of the bar and is greater at the top than at the bottom except for the B-35 24-in. head-free joints, where the average is 0.026 in. for the top and 0.052 in. for the bottom. The results for north and south rails agree closely. On the Pennsylvania out-to-out measurements for the various stretches show that the bars have moved toward each other a

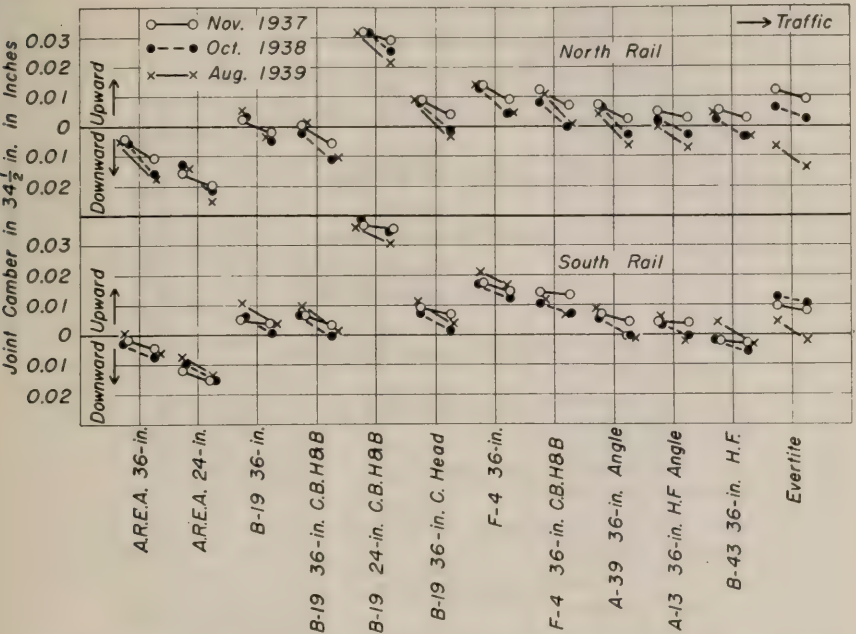

Fig. 2. Joint Camber in 34½ in. at Leaving and Receiving Rail Ends for 60 Joints in Each Test Stretch on P.R.R. in 1937, 1938 and 1939.

distance averaging from 0.015 to 0.036 in. in the 12 stretches of 60 measured joints in each stretch, with the greater movement at the top of the bar. Exceptions to this were: (1) B-19 36-in. controlled head-bearing bars and A-39 36-in. angle bars moved toward each other at the top and away at the bottom; (2) A-13 36-in. head-free angle bars moved away from each other both at the top and at the bottom (the outward movement being explainable by a reduction in bolt tension from 20,000 lb. in 1937 to 8,000 lb. in 1939); (3) Evertite joint bars moved toward each other with the greater movement at the bottom.

Rail surface profile measurements were obtained at the rail joints on the running surface of the rail along a line near the middle of the head. This measurement was made on 15 joints on the north rail and also on the south rail in the various test stretches. The reference points for the profile instrument were located in the base of the rail. The instrument extends over a length of 48 in. and readings were taken along the running surface of the rail between a point 20 in. from the leaving end and a point 20 in. from the receiving end. It is believed that the changes from year to year at a point 20 in. from a rail end give a fair indication of the surface wear and flow of the rail at points away from the joint, and that changes at a point ¼ in. from the rail end give a fair indication of present wear, batter, and perhaps bending at and near the rail end, although the batter will later have a different distribution along the rail and the whole length of the profiles will have to be considered in judging of the batter action. In Fig. 3 the changes in the elevation of the rail surface taken from the profile measurements on the Santa Fe occurring from 1938 to 1939 have been plotted for the two points, one 20 in. and one ¼ in. from the rail end. Each point is the average value for

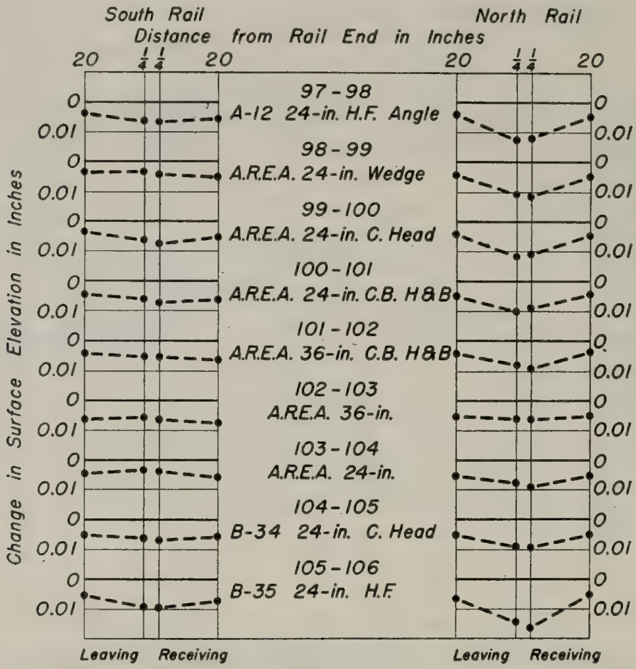

Fig. 3. Change in Elevation of Rail Surface from 1938 to 1939 at ¼ in. and 20 in. from Rail Ends for 30 Joints in Each Stretch on A.T. & S.F. Ry.

15 joints. It is seen that the wear at 20 in. is about the same for both the non-end-hardened north rail and the end-hardened south rail and that the average of both is 0.005 in. The average change at the ¼-in. point is 0.006 in. on the end-hardened south rail and 0.010 in. on the non-end-hardened north rail. In two of the test stretches on the end-hardened rail, the wear at 20 in. is greater than the combined effect of wear, batter and bending at ¼ in. from the rail end.

In Fig. 4 are plotted the changes in the rail surface profile measurements for the 20-in. and the ¼-in. points on the Pennsylvania from 1938 to 1939. Here again the average change or wear at the 20-in. points is about the same for both north and south rails. The average wear is 0.007 in. The change at ¼ in. from the rail end is 0.009 in. on the non-end-hardened north rail and 0.006 in. for the end-hardened south rail. In seven stretches on the end-hardened rail, the wear at 20 in. is greater than the combined effect of wear, batter and bending at ¼ in. from the end. It will be seen that the change is actually upward at ¼ in. on the leaving rail in one stretch. Although the wear is small as yet, the indications on both railroads are that end hardening reduces the amount of wear and batter near the rail ends.

Bolts on the Santa Fe test stretches were tightened by means of a 24-in. wrench in March 1939. The average bolt tension in 54 joints was 15,600 lb., ranging from an average tension of 11,500 lb. in Mile 104-105 to 21,700 lb. in Mile 100-101. In September 1939, 270 additional joints (30 in each mile) were measured and the average bolt tension was found to be 6,900 lb., ranging from an average bolt tension of 4,900 lb. in Mile 104-105 to 10,900 lb. in Mile 98-99. The data show a variation in bolt tension.

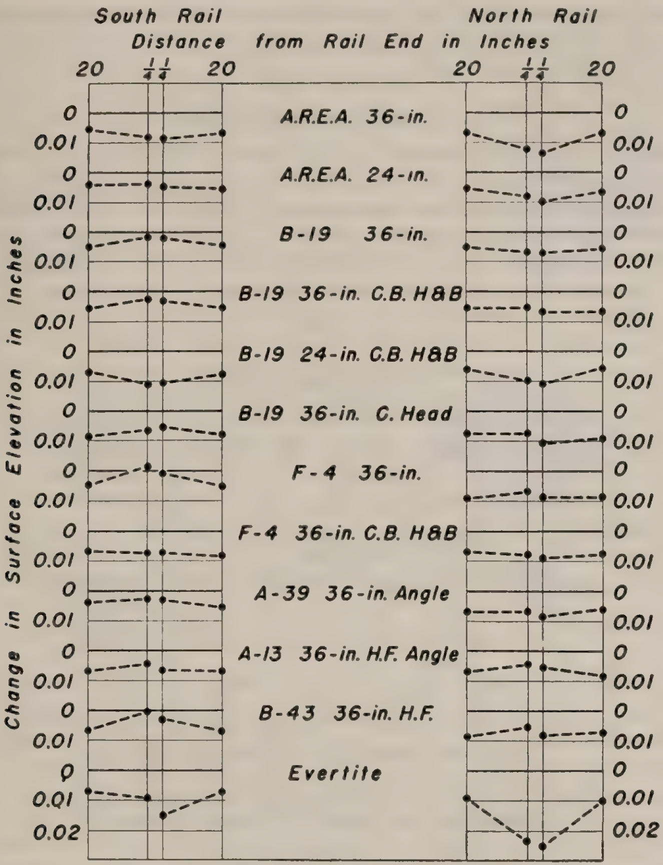

Fig. 4. Change in Elevation of Rail Surface from 1938 to 1939 at ¼ in. and 20 in. from Rail Ends for 30 Joints in Each Stretch on P.R.R.

In May 1939 bolts were tightened on the Pennsylvania test stretch by means of a mechanical nutter. An effort was made to obtain a tension of 12,000 lb., but the results show that with the equipment used it is difficult to secure tensions approaching uniformity.

To learn whether a change in temperature of a joint will result in a change in bolt tension, measurements were made in six joints early in the morning and in the middle of the day at temperatures of about 50 deg. and 90 deg. F., respectively. The results show that the change in bolt tension, if any, was less than the errors in observation.

The rail gaps on both test railroads were measured in February and July, 1939. The average change in gap on the Santa Fe was 0.205 in. for an average temperature change of 83 deg. F. The average change in rail gap on the Pennsylvania was 0.182 in. for an average temperature change of 83 deg. F. Unrestricted movement for such a change in temperature is about 0.25 in. This means the average residual temperature stress in the rail was about 4,000 lb. per sq. in. The changes in rail gaps on the two railroads range from zero to ½ in. Less than four percent of the gaps showed no change from February to July, and these individual joints were scattered over the test stretches. Grouping of "frozen joints" occurred in 1938 in only a few spots, particularly in the locations having bolt tension in excess of 20,000 lb.

Observations on Welded Track

Measurement of temperature strain in rail taken on two stretches of welded track since the summers of 1935 and 1936 on the Delaware & Hudson Railroad at Schenectady, N. Y., and on the Bessemer & Lake Erie Railroad at River Valley, Pa., was repeated in the summer of 1939. As may be recalled, changes in length of gage lines (strain) over a wide range of temperature have been measured to determine the temperature stresses developed at points along the welded track, particularly throughout the end portions where the principal rail anchorage is developed.

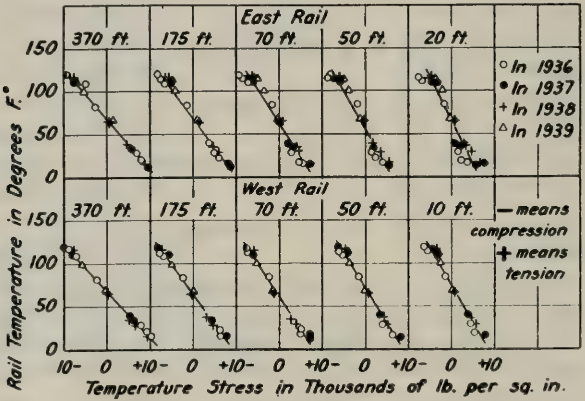

Fig. 5. Temperature Stresses in Rail near One End of a Welded Stretch—Delaware & Hudson Railroad.

It was found in these latest tests that, in general, these two stretches of welded track were maintaining the stable position and condition that had been found in previous observations. Up to the time of the last measurements no weld failures had occurred in the test stretches in the past year. It should be stated that the number of failures over the whole period has been small or nil in the tracks on which the measurements have been made. Because of the lack of new or unusual action, detailed discussion of these tests will not be made. However, Fig. 4 on page 645 of the Proceedings for 1939, Vol. 40, is reproduced here in revised form as Fig. 5 of this report to show the results of the three sets of measurements taken in 1939 at five locations on each rail at one end of the test stretch on the Delaware & Hudson Railroad. The new values are plotted as triangles. For each location the temperature stress in the rail relative to the stress at 73 deg. F. is plotted against the temperature at which the readings were taken. The new values are seen to group themselves with those of three previous years thus indicating that no material adjustments or changes of relationship had taken place during the period of time over which the test measurements have been made.

In the figure, measured values are given for a change of about 50 deg. F. in temperature each way from 73 deg. F., which may be considered as a medium temperature. For this range the temperature stress at 370 ft. from the end of the welded stretch is seen to be about 10,000 lb. per sq. in. compression for a rise of 50 deg. F. and 10,000 lb. per sq. in. tension for a fall of 50 deg., while near the end of the welded stretch where the welded rail connects with a similar welded stretch by means of joint bars, the temperature stress is about 5,000 lb. per sq. in. for a 50-deg. rise and a 50-deg. fall of temperature. For smaller changes in temperature either way, the temperature stresses developed are proportional to the temperature changes. If the rail were laid at other than this medium temperature, the data indicate that the stresses developed will be proportional to the change from the laying temperature. For greater changes than 50 deg. F., the temperature stress will probably also be proportional to the change in temperature, although it is not known what the limiting value of the rail anchorage may be.

Information has been received from the Bessemer & Lake Erie Railroad to the effect that a break occurred January 30, 1940, at joint No. 87 of the east rail when the air temperature was 8 deg. F. Despite this low temperature the rails separated only ½ in. at the break. The anchorage force required to limit the separation to this small amount must have been large. It is evident the anchorage there developed by the ties and fastenings, though probably much higher than normal, was adequate to hold the contraction to a low value. It is worth noting that the location of the break was at a place on the track where the measurements in the summer of 1939 indicated a change of strain in the rail (increase at one point and decrease in another point a few rail lengths apart) as compared with the readings of 1938, so that unusual forces may have been developed.

It is planned to continue the measurements at appropriate intervals in the future.

Tests With the Rolling-Load Machine

The purpose of the rolling-load rail joint testing machine* is to make laboratory studies of long time repetitive tests of rail joints to cover some of the many variations, forms of the joint bars, manner of failure, wear of bar and rail fishing surfaces, sources of failure, life of joint bars under repetitive loading given by very heavy wheel loads and moderately heavy wheel loads and lighter wheel loads, and possible relations between cycles of loading and the fatigue strength of joint bars of different form and different material, together with such other aspects of the problem as fit and wear and normal and abnormal stresses and bearing pressures between bar and rail and the magnitude of bolt tension.

The stroke or travel of this rolling-load testing machine is 33-in.* As operated the wheel giving the load in rolling from a point 6 in. to the left of the center of a 36-in. span on to the right support applies a positive bending moment (downward deflection) in the part between the two supports, and then in passing on over an overhanging cantilever portion for a distance of 9 in. produces a negative moment (upward deflection). The maximum negative moment applied at the center of the joint is one-half of the maximum positive moment developed at the same point. This relation between the magnitudes of the positive and the negative moments approximates fairly well to the relations of the two moments generally developed in track. The 36-in. span gives a distribution of positive moment that approximates that produced in a rail by a group of wheels. In the tests so far made, a load of 44,400 lb. has generally been used, which applies a maximum positive bending moment of 400,000 in.-lb. (that being the moment that was used as a criterion in the calculations and design of joint bars in the Sixth Progress Report) and a maximum negative moment of 200,000 in.-lb. The testing machine operates at 27 cycles per minute, 39,000 cycles per day, and 1,000,000 cycles in 26 days.

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* This machine was described in detail and illustrated on pages 649–652 of the Proceedings for 1939, Vol. 40.

Observations and measurements of the test joints are made periodically, including inspection for cracks by means of magnaflux. Failure may come through variations in quality of metal, particularly in the fatigue strength, and in the conditions of fit and loading productive of high combined stresses or lowered resistance. Among the many variations in the conditions of joint bar and rail that have been found to affect markedly the number of cycles or applications of load that produce fracture in joint bars is one that had not been suspected. This is the presence of a slight distortion of the head and the flange of the rail for a few inches along the upper and lower fishing surfaces, in effect decreasing the fishing height of the rail, back to say four to six inches away from the rail end, a condition probably produced in the hot-sawing operation. The effect of this distortion and decrease in fishing height is to pinch the joint bar for a short distance at the top or bottom fishing surface, or both, when bolt tension and wheel load bending moment action combine to apply bearing stresses on the bar fishing surfaces at just the time when the fibers of the bar (top or bottom) are given their greatest change in longitudinal strain (change in fiber length), while the adjacent rail fibers are not under strain, with the accompanying slipping of the surfaces in contact or corresponding distortions of surface layers. For lack of a better term this distorted condition at the fishing surfaces near the rail ends is being termed a "pinching condition".

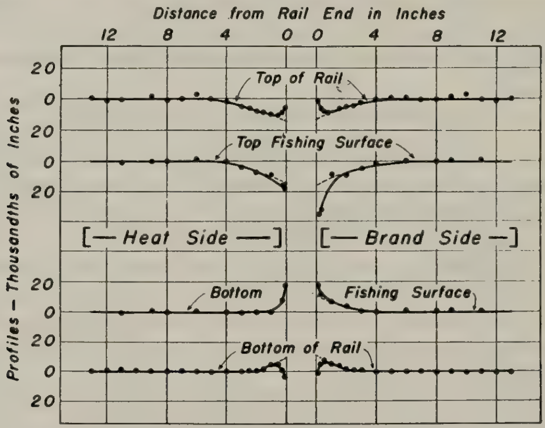

Fig. 6. Profiles of Top and Bottom Fishing Surfaces near Rail End on Heat Side and Brand Side of a Rail Distorted in Hot Sawing.

Fig. 6 shows the profiles of the top and bottom fishing surfaces on the two sides (heat side and brand side) of a rail for a few inches from its end—one of the worst examples found in a few pieces of new 112-lb. rails especially selected and examined. Here the maximum downward distortion of the top fishing surface at the rail ends is 0.035 in., which is on the brand side of the rail; it decreases to zero at 4 in. from the end. On the same side the maximum upward distortion of the bottom fishing surface is 0.018 in. On the heat side the corresponding distortions are 0.020 and 0.018 in., respectively. It will be noted that the top surface of the rail at its extreme end is distorted upward, as shown by the profile at the top of the diagram, and that of the bottom of the rail (shown below) is distorted downward, and also that at an inch or more from the end the whole head has been bent downward and the bottom flange bent upward. It should be noted that in all cases fins and burrs at the ends of the rail had been removed from the rail ends and that the first measurement given on the diagram was made at ⅛ in. from the rail end. The top surface was usually much the worse. In another set of samples comprising 16 rail ends, hot sawed at the mill and showing considerable distortion, there was no pronounced difference in the distortion on the heat and the brand side of the rail. Information is not available on how common these defects may be in the rollings at the mills, or how frequently they have been noted in track, or what the remedy is.

In the rolling-load tests, the distortion or pinching action resulted in abraiding or gouging of the metal of the joint bars, more or less severely, for a short distance at the rail end or wherever the high pressure is applied to the bar. This gouging was much more severe at the top of the bar than at the bottom, as might be expected because of the much higher pressures developed at the top fishing surface. When gouging occurred at the top, fatigue cracks in the top of the bar developed much earlier than when no gouging was present. For most of the rolling-load tests the rail ends were laboratory sawed, and these rails are designated as normal rail ends; they are free from the end distortion above described. Generally, with the laboratory sawed rail end little or no gouging of the fishing surfaces occurred.

In the tests two of the joints withstood a very large number of repetitions of load without apparent injury, and their test was discontinued. All the other joints gave fatigue failures; that is, the failure was from a progressive fracture of the metal in the joint bar. Fig. 7 is a view of the transverse section of a pair of bars with fatigue failure in the bottom of the right bar at 649,000 cycles. Fatigue cracks had developed in the top of both bars (one first noticed at 220,000 cycles) but, although the top of both bars received severe gouging, these cracks progressed downward only slowly to points about

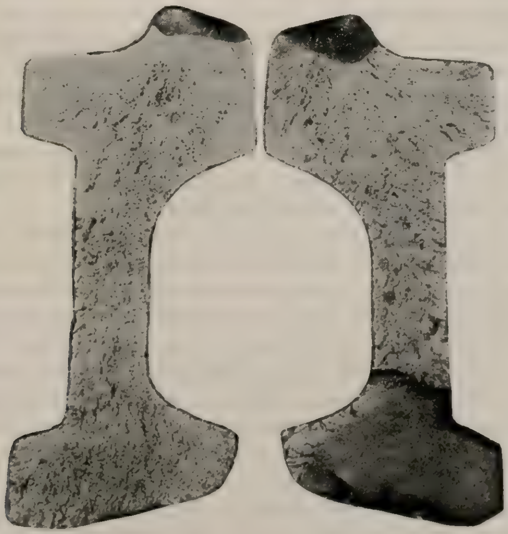

Fig. 7. View of Transverse Section of AREA 36-in. Joint Bars after Fatigue Failure in Bottom of Right Bar at 649,400 cycles.

¼ in. and ½ in. from the top. No gouging was found on the bottom of the bars. A crack in the bottom of a bar a short distance from a rail end, first noticed at 645,000 cycles, progressed rapidly upward to the point shown in the figure to failure at 649,000 cycles. Except for one joint, in which heavy gouging occurred at the top of the bars from a badly distorted or "'pinching" rail end and from this a top crack continued downward to failure, all the new or unused joints failed by a fatigue crack at the bottom of the bar. Generally failure at the bottom is to be expected because tension is developed at the bottom of the bars for positive moment and by the loading arrangement the positive moment is double the negative moment. In general the bearing between the fishing surfaces at points near the rail ends was full and well distributed.

It seems best to report at this time only a summary of findings for the various groups or divisions of the test, omitting details, and to assume that the relatively few tests give representative indications notwithstanding the variations in properties of the bars tested. Unless otherwise stated the load used was 44,400 lb. (positive bending moment 400,000 in-lb.) and bolt tension 15,000 lb. The number of joints in a group varied from one to four.

The following summary gives the principal findings for the tests:

1. *Normal rail ends.*—For all joints with unused bars and normal rail ends (not having pinching ends), final failure occurred from a fatigue crack at the bottom of the bar, although in many cases cracks developed in the top of the bars earlier in the test but progressed only slowly. Four joints with ordinary run of mill bars (including one joint having normal bottom conditions and one rail end "pinching" at the top) and with standard conditions of load and bolt tension gave bottom fatigue failures at an average of 576,000 cycles.

2. *Bottom fishing surface machined.*—One joint with bars having 0.02 in. depth of metal machined from bottom fishing surface along the length failed at 722,000 cycles (bottom fatigue crack), which may indicate some improvement through removing part of roughness and decarburization.

3. *Bar steel specially heat treated.*—Two joints of bar steel specially heat treated showed increased resistance to failure—one failed at 701,000 cycles, and the other resisted any development of fatigue cracks at the bottom for 1,507,000 cyles, when the test was discontinued.

4. *Rail steel specially heat treated.*—In two joints of rail steel specially heat treated final failure occurred from a fatigue crack at 226,000 and 240,000 cycles, showing lower resistance to fatigue than given by the mill run bars.

5. *Distorted rail end.*—Two joints having one rail end distorted in the hot sawing process, so that a "pinching" end condition resulted in severe concentration of bearing pressures near the rail ends, gave bottom failures in the bars at the point where gouging was severe at 268,000 and 280,000 cycles, and one joint having pinching conditions that produced heavy top gouging of the bars gave a top failure at 286,000 cycles. The last named is the only joint with unused bars in which failure occurred at the top of the bar.

6. *80-percent load.*—Using a load of 35,500 lb. (80 percent of the standard load) and normal rail ends, one joint gave a bottom fatigue failure at 1,501,000 cycles, a considerable increase in life over the test made with a load of 44,400 lb. A second joint with 80-percent load had a shorter life. It failed at 810,000 cycles.

7. *5,000-lb. bolt tension.*—Using 5,000-lb. bolt tension instead of 15,000 lb. but applying the standard load of 44,400 lb., one joint resisted fatigue failure for 1,702,000 cycles, when the test was discontinued.

8. *35,000-lb. bolt tension.*—Using 35,000-lb. bolt tension instead of 15,000 lb., three joints gave bottom fatigue failures at 506,000 and 198,000 and 541,000 cycles. In the

second joint (198,000 cycles) the bearing on the lower fishing surfaces at and near a rail end was narrow and concentrated, while in the other two the corresponding bearing was full and well distributed.

9. *Bars cracked in track.*—Two joints with bars having cracks in the top about 0.2 in. in depth, which were developed in service in track, gave top fatigue failures through these cracks at 166,000 and 387,000 cycles. The cracks had been developed in track service at points where heavy gouging was present when the bars were taken from the track. The condition of the previous load and traffic is not known.

It may be of interest to state that for the standard loading of 44,400 lb. and bolt tension of 15,000 lb. used in the tests, the measured stresses in the bars under full load varied considerably with the fit of the bars and other conditions, as is to be expected, but in general the maximum stress at the bottom fiber ranged from 35,000 to 45,000 lb. per sq. in. tension and that in gage lines near the top fiber, from 40,000 to 60,000 lb. per sq. in. compression. These values include the initial stresses developed in the bar due to bolt tension and the resultant pressures, as well as the flexural stresses due to the applied load.

Study has been given in more detail to the properties of the material, its fatigue strength, the location and growth of cracks, the nature of the fishing bearings, and the sources of the variations in results.

Effect of Flat Wheel

A pair of flat wheels that had been taken out of service as unfit for running was placed in the truck of a loaded 70-ton car. Stresses in the base of the rail and depressions of the rails were measured with magnetic gages as these flat wheels were run over the instruments. In making the runs, the position of the contact of the flat spot on the rail was regulated to come as nearly over the instruments as practicable; the variation in position would probably give less than the actual value directly under the flat spot in a number of runs. The running speed was limited to 30 miles per hour because of the thin rims of the wheels.

Fig. 8 gives profiles of the flat spots on the two wheels. The ordinates were measured from a true circle. It will be seen that the total length of the flat spots was about four inches. The maximum depth of the two flat spots was about ⅛ in.

Fig. 9 represents to scale typical records of rail stress and rail depression as a flat wheel and a round wheel pass the instruments at 31 miles per hour. (The actual records are clear and definite but could not be reproduced in an engraving.) It will be noted that the rail stress under the normal wheel is 11,000 lb. per sq. in. and that at the flat spot is 23,000 lb. per sq. in. The record at the flat spot illustrates the great rapidity of change in stress and depression as the flat spot passes over the instruments.

The maximum values of the stress in the base of rail and the depression of rail made by both wheels at the various speeds are shown in Fig. 10. The open circles are for the flat spot on the left wheel and the closed circles are for that on the right wheel. The lowest speed used was 11 miles per hour and the highest about 32 miles per hour. It is interesting to see that a definite maximum for the stresses and depressions with the speed range used occurs at 20 to 22 miles per hour and that some of the stresses are as high as 25,000 lb. per sq. in. even in this 131-lb. rail. The maximum values of the depressions are from about 0.21 to 0.24 in. Above and below this speed of 20 to 22 miles per hour the values of the stress and depression are smaller, though they appear to be rising again somewhat as the highest speed used is approached, indicating that still higher stresses and depressions might have been developed beyond the range of the test speeds.

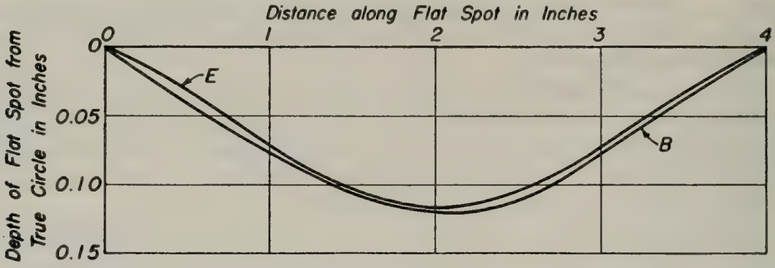

Fig. 8. Profile of Flat Spot on the Two Wheels—Ordinates Measured from True Circle.

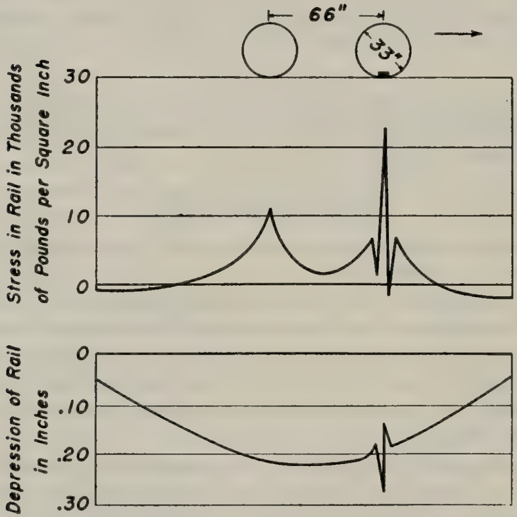

Fig. 9. Stress in Base of Rail and Depression of Rail as Flat Wheel and Round Wheel Pass the Instruments.

The other six car wheels in passing over the instruments developed an average stress of 10,000 lb. per sq. in. and a rail depression of 0.18 to 0.20 in., an increase over the normal amount of 2½ times for the stress and about 1⅓ times for the depression. There is some indication that there may be a lesser peak or hump in the curves at the lower speed of 13 or 14 miles per hour but the number of runs at this speed was too small to draw a definite conclusion.

An approximate analysis for the effect of the flat spots modified to take account of the car spring indicates that with the assumptions made the maximum depressions and stresses should occur at about five miles per hour for these flat spots. The stress calculated by the analysis for five miles per hour is 27,000 lb. per sq. in. The assumptions of the analyses, however, are undoubtedly not representative of the actual conditions for the higher speeds in several respects. The most important weakness of the analyses for the flat spot is probably in the assumption of continuous contact with the rail surface. Consideration of the relations involved would indicate it is very unlikely that

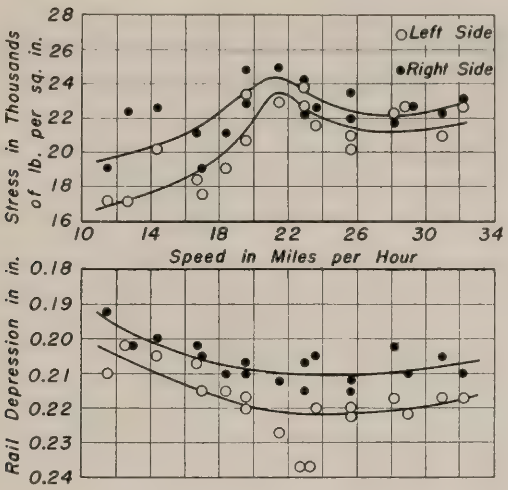

Fig. 10. Stress in Base of Rail and Depression of Rail under Flat Wheels at Various Speeds.

contact can be maintained when the contour changes so quickly and the spot is so deep. Loss of contact permits the wheel to be accelerated downward by the car spring, and the rail is similarly accelerated upward by the unbalanced reactions from the track. Large impacts are then developed on establishment of contact and this action is much more severe and complicated than when contact is maintained.

The film records for the stresses and depressions under the flat wheels show that the stresses and depressions are developed very quickly. With the film speed used, however, it was not possible to determine just how quickly the changes occurred. There is no doubt that the changes occurred too quickly for the oscillograph galvanometers to indicate the full amount of the stress and the depression. It would be very desirable to make further tests of wheels with flat spots using equipment suitable for recording the rapidly changing values more accurately. Such equipment is now being developed. It is hoped that it will be in usable form in the near future.

Tests were also made on the effect that batter in the rail at the joints and away from the joint has on the stresses developed. These tests will be reported at a later date.

Testing Equipment

The staff has continued the study of electrical strain measuring and recording instruments and as funds have become available purchases have been made of items that seem most immediately useful and most adaptable to probable future needs. This equipment though somewhat limited in amount will soon be in usable form for field tests.

Development work is being done in connection with the use of the resistance strip gage. Experimental amplifier units have been made up and are being tested. These developments show considerable promise for improving the usefulness and reliability of the strip gage and will give advantages in calibration, frequency response, and elimination of certain troubles experienced previously.

It is hoped in the future when funds are available to increase the number of measuring and recording units with the types found most suitable.

Sixth Progress Report of the Joint Investigation of Fissures in Railroad Rails

By H. F. Moore

Research Professor of Engineering Materials, University of Illinois,
in Charge of the Investigation

I. Introduction

1. **Previous Reports of the Investigation.**—The previous work of the investigation has been published in five progress reports which appear in the AREA Proceedings and as reprints of the University of Illinois Engineering Experiment Station.*

2. **Organization of the Investigation.**—This investigation is sponsored jointly by the Association of American Railroads, the Rail Manufacturers' Technical Committee and the University of Illinois. It is carried on as part of the research work of the Engineering Experiment Station, Dean M. L. Enger, director, and is under the immediate charge of the Department of Theoretical and Applied Mechanics, Professor F. B. Seely, head.

An advisory committee has been appointed by the Association of American Railroads and the Rail Manufacturers' Technical Committee, and the present membership is as follows:

Association of American Railroads—Rail Committee:

- W. H. Penfield, Chief Engineer, Chicago, Milwaukee, St. Paul & Pacific Railroad (Chairman)†
- J. E. Armstrong, Chief Engineer, Canadian Pacific Railway
- W. C. Barnes, Engineer of Tests, Rail Committee, AREA
- L. H. Bond, Chief Engineer Maintenance of Way, Illinois Central System
- C. B. Bronson, Inspecting Engineer, New York Central System
- E. E. Chapman, Mechanical Assistant to Assistant to Vice-President, Atchison, Topeka & Santa Fe Railway
- R. Faries, Assistant Chief Engineer–Maintenance, Pennsylvania Railroad
- P. Petri, Chief Engineer Maintenance, Baltimore & Ohio Railroad
- W. P. Wiltsee, Chief Engineer, Norfolk & Western Railway
- L. Yager, Assistant Chief Engineer, Northern Pacific Railway

Rail Manufacturers' Technical Committee:

- F. W. Wood, 2429 Keyworth Ave., Baltimore, Md. (Chairman)
- F. W. Bendell, Manager Railroad Materials and Commercial Forgings Bureau, Carnegie–Illinois Steel Corporation
- O. U. Cook, Assistant Manager, Department of Metallurgy, Inspection and Research, Tennessee Coal, Iron & Railroad Company

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* The First Progress Report appeared in the AREA Proceedings, Vol. 36, pp. 1065–1090 (1935) and in Reprint No. 4 of the Eng. Expt. Station, University of Illinois, copies of which are exhausted.

The Second Progress Report appeared in the AREA Proceedings, Vol. 37, pp. 998–1012 (1936) and in Reprint No. 8 of the Eng. Expt. Station, University of Illinois.

The Third Progress Report appeared in the AREA Proceedings, Vol. 38, pp. 645–673 (1937) and in Reprint No. 11 of the Eng. Expt. Station, University of Illinois.

The Fourth Progress Report appeared in the AREA Proceedings, Vol. 39, pp. 807–856 (1938) and in Reprint No. 12 of the Eng. Expt. Station, University of Illinois.

The Fifth Progress Report appeared in the AREA Proceedings, Vol. 40, pp. 655–686 (1939) and in Reprint No. 14 of the Eng. Expt. Station, University of Illinois.

† Mr. Penfield was appointed chairman on March 14 to succeed Mr. J. V. Neubert, resigned, Mr. Neubert having been chairman of the committee for four years.

E. F. Kenney, Metallurgical Engineer, Bethlehem Steel Company
L. S. Marsh, Manager, Department of Inspection and Metallurgy, Inland Steel Company
J. H. Reece, Chief Inspector, Colorado Fuel & Iron Company
C. F. W. Rys, Chief Metallurgical Engineer, Carnegie–Illinois Steel Corporation

The test party carrying out the investigation includes the following:

Regular Staff:

H. F. Moore, In Charge of Investigation (Services furnished by Engineering Experiment Station, University of Illinois)
H. R. Thomas, Engineer of Tests, General detailed oversight of work, mathematical interpretation of test results, field tests
R. E. Cramer, Metallographic and chemical tests
S. W. Lyon, Laboratory tests of materials
N. J. Alleman, Laboratory tests of materials and rail specimens
J. L. Bisesi, Non-destructive detection of cracks and fissures, field tests

Test Assistant:

R. S. Jensen, Non-destructive tests, field tests

Mechanicians:

H. Belles, H. C. Boswell, F. A. Ferris, H. H. Griesheimer, M. K. Shafer and H. Musgrove

General Assistant in Machine Shop:

C. Boley

Student Assistants: (part time)

G. B. Bliss, R. S. Hutton, E. C. Lauck, P. A. Ramsdell, J. C. Leming, C. M. Middlesworth and J. S. Shapland.

Clerk and Stenographer:

Rogene Strode

During the past year Mr. E. C. Bast, assistant in chemical and metallurgical work, has accepted a position in the testing laboratory of the Atchison, Topeka and Santa Fe Railway. The following student assistants have left the investigation: Mr. R. J. King to go with the Caterpillar Tractor Company, Mr. C. P. Wampler to join the research staff of the A. O. Smith Corp., Messrs. R. G. Emerson, T. J. Riggs and Hall Hood to accept business openings or to take up study elsewhere.

II. Service Failures of Control-Cooled and Brunorized Rails

By R. E. Cramer and H. F. Moore

1. Failures Reported to the Test Party. — In September, 1939, there were 2,088,000 tons of control-cooled rails and 93,425 tons of Brunorized rails in railroad service. The length of service of these rails varies from a few months to about five years.

All together the test party has received reports of six control-cooled rails and six Brunorized rails which have either broken in track or been found by a detector car, and which were reported as rails with transverse fissures. Laboratory tests as described in detail on the following pages have shown that four of the control-cooled rail failures

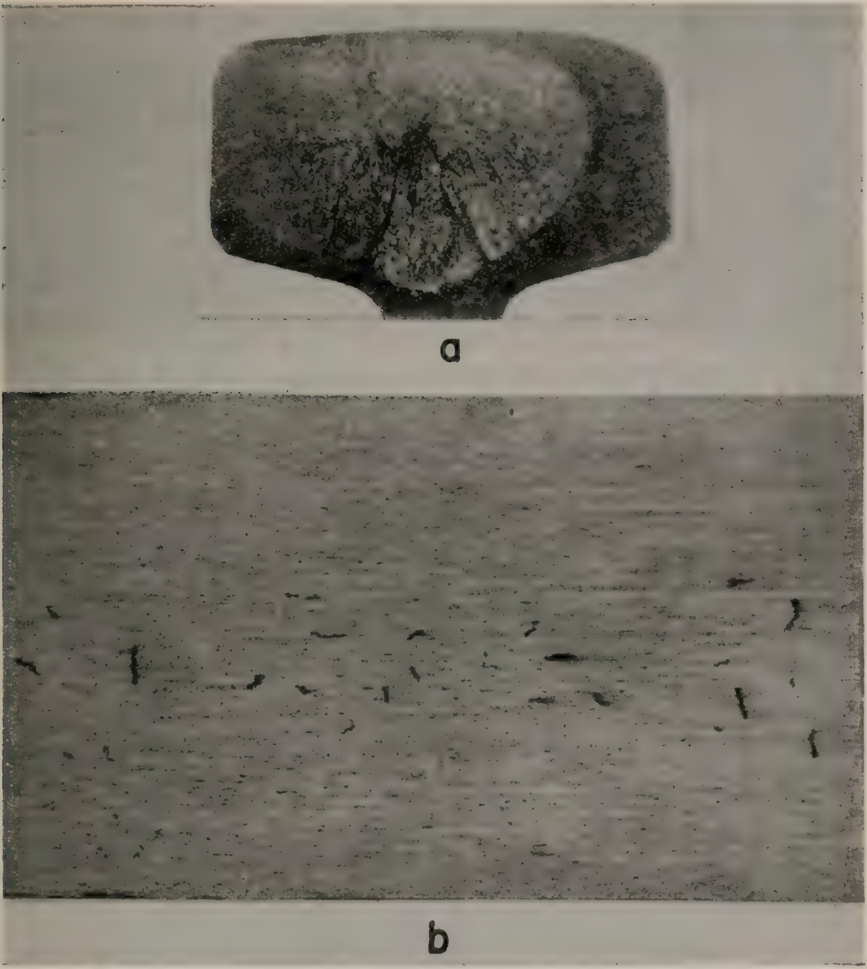

Fig. 1. Failed Brunorized Rail.
(a) General View of Fracture.
(b) Etched Horizontal Slice from Head.

were *not* transverse fissures as defined by the AREA and careful etch tests have failed to locate any shatter cracks in any of the control-cooled rails. Previous to the receipt of the first report of a failed control-cooled rail by the test party, Mr. W. C. Barnes had reported to the AREA Rail committee one or two failures of rails which had been control cooled in an experimental cooling container and were not supplied under the present recommended practice for such rails.

2. **Failures of Brunorized Rails (Old Process used until April, 1938).**— The six Brunorized rails which have developed fissures were all reported from the tracks of the Illinois Central Railroad by Mr. L. H. Bond, chief engineer maintenance of way. They were all rolled in December, 1937 before the Brunorizing process was

modified to require that the rails be held at a temperature above 1,000 deg. F. for two hours before entering the Brunorizing furnace.

Four of the failed Brunorized rails have been examined and these failures were typical transverse fissures with shatter crack nuclei. Etch tests of slices cut from these four rails a short distance from the fractures show some shatter cracks. A detailed statement concerning tests of one of these rails will serve for all of them. This rail failed July 16, 1939. A six-inch section of the rail containing one face of the fracture was furnished for tests. The surface of the fracture was quite rusty which made it difficult to photograph. Fig. 1 (a) shows the fracture. This is a typical transverse fissure with a well-defined nucleus about 7/32 in. in diameter and the fissured area covers about 80 percent of the area of the head.

A section of the rail head, 5⅜ in. long, was sawed into three slices with the top slice ⅝ in. thick. These were ground smooth and etched in hot 50 percent hydrochloric acid for shatter cracks. Fig. 1 (b) shows shatter cracks in a horizontal plane approximately ⅝ in. below the tread of the rail.

No transverse fissure failures have been reported to the test party of rails treated by the Brunorizing process now in use, which includes a two-hour holding period after the rail is rolled.

3. Failures of Control-Cooled Rail

Rail from the Norfolk & Western Railway. — One control-cooled rail which had broken in service was sent to the laboratory by Mr. W. P. Wiltsee, chief engineer, Norfolk & Western Railway Company, for examination. This rail failure had been reported as a transverse fissure. The cause of failure was found to be surface seams on the under side of the base. The rail was sliced and etched and found to be entirely free of shatter cracks. It was *not* a transverse fissure failure.

Rail Failure on the Erie Railroad.—On February 16, 1939, a rail failed on the Meadeville division of the Erie Railroad at Ashville, N. Y. The foreman's report gave the following information—(quotation from letter of W. C. Barnes to H. F. Moore, March 30, 1939).

> "Controlled-cooled rail, rolled in 1935, 112-lb. AREA, heat No. 22030-6-A, failure occurred on straight track, 10-in. slag ballast, rail little worn, temperature 2 deg. F. below zero when found disclosing 67 percent transverse fissure located 2 ft. 9 in. from receiving end of rail."

The broken pieces of the rail were sent to the University of Illinois for examination. Fig. 2 (a) is a photograph of these pieces showing the broken base, and Fig. 2 (b) shows an end-on view of the fracture. The fracture does not resemble a transverse fissure, a compound fissure, a vertical split head, or a horizontal split head. There is no evidence of a nucleus nor of the "smooth area" found in internal fissures. The fracture indicates a sudden break starting in the base of the rail and extending upward through the web and head. A six-inch section of the rail was sliced and etched for shatter cracks but no shatter cracks were found. This failure can therefore be classed as a "broken base" failure occurring when the temperature was two degrees (F.) below zero and shows no evidence of being any kind of internal fissure failure.

Rail Failure on the Louisville and Nashville Railroad.—In letters from G. R. Smiley, chief engineer, Louisville & Nashville Railroad and from Mr. Barnes the following information is given.

> "100-lb. AREA section rail, heat No. 850,996, letter F, ingot 25, original length 39 ft., rolled in November 1936, and laid in 1936, at location 2,808 ft. south of M.P. 29. Cincinnati Corbin subdivision, being the east rail on the northbound main

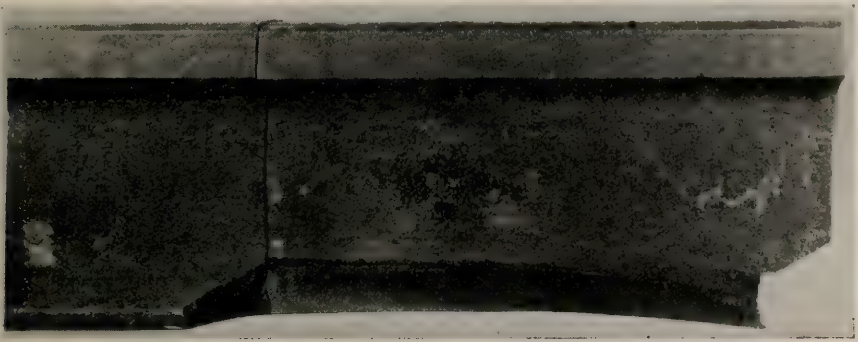

Fig. 2 (a). Controlled-Cooled Rail Failure from Erie Railroad. Base break and fracture extending through web and head.

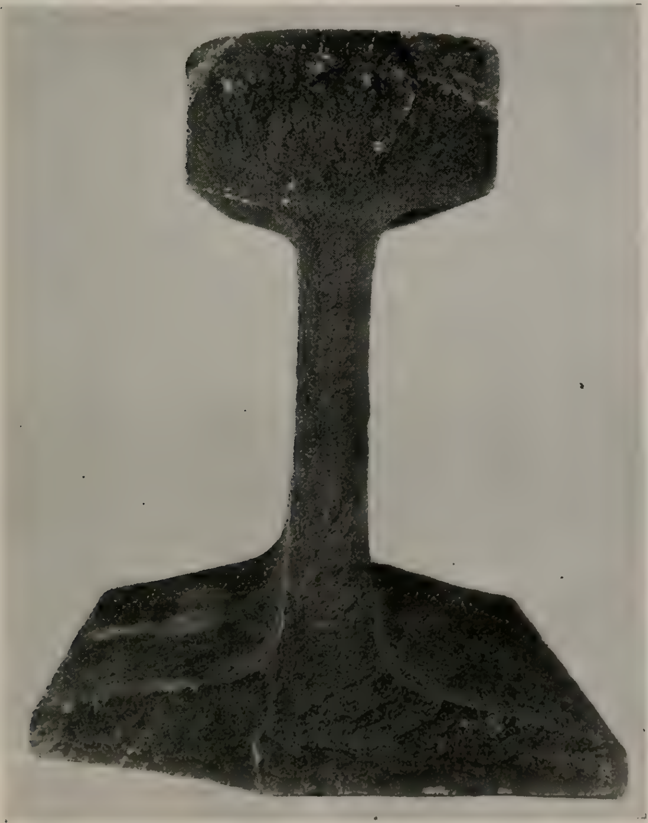

Fig. 2 (b). Control-Cooled Rail Failure from Erie Railroad. Note the absence of any smooth bright "fatigue" area.

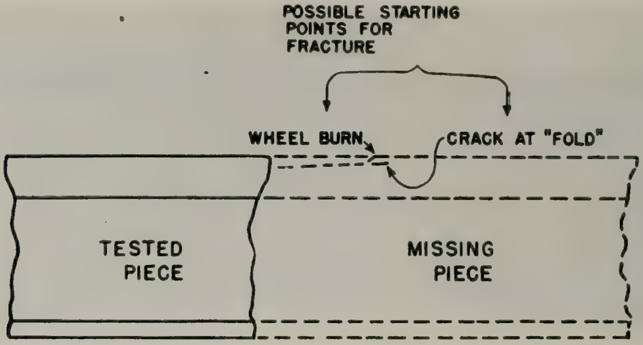

Fig. 3. Sketch Showing Probable Path of Fracture in Missing Piece of Louisville & Nashville Rail.

> track on the high side of 4¾ deg. curve, elevation of curve at break 5 in. Rail was discovered to be broken on 12/15/38. Gage of track at break 4 ft. 8½ in. Distance between edges of ties at break 12 in. Creosoted oak ties in good condition, rock ballast; condition of line and surface reported good. Break described as 40 percent transverse fissure about 3½ ft. from receiving end of rail and the following note also appears—'No indication on Sperry rail chart'.
>
> "Maximum speed of passenger trains around this curve—50 to 55 m. p. h.
> "Maximum speed of freight trains—40 to 45 m. p. h."

One piece of the broken rail was sent to the University of Illinois for study. Unfortunately the other piece cannot be located. At first glance the failure resembled a transverse fissure, and it is not at all surprising that it was reported as a fissure. However, a closer examination of the fracture failed to show any evidence of the nucleus which is characteristic of internal fissures, and the general trend of the fracture indicates that its starting point was located in the missing piece of rail as indicated in Fig. 3.

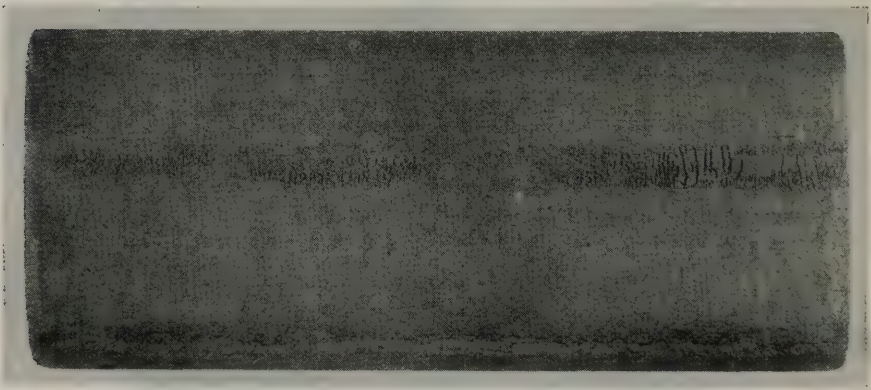

Fig. 4. Top Slice of Rail Adjacent to Fracture, After Etching in Hot 50 Percent HCl Solution.

Note fold of flowed metal along lower edge or gage corner of head and "wheel burned" streak near middle of head which shows numerous small cracks. Both of these features extended the full length of the specimen sent to the laboratory.

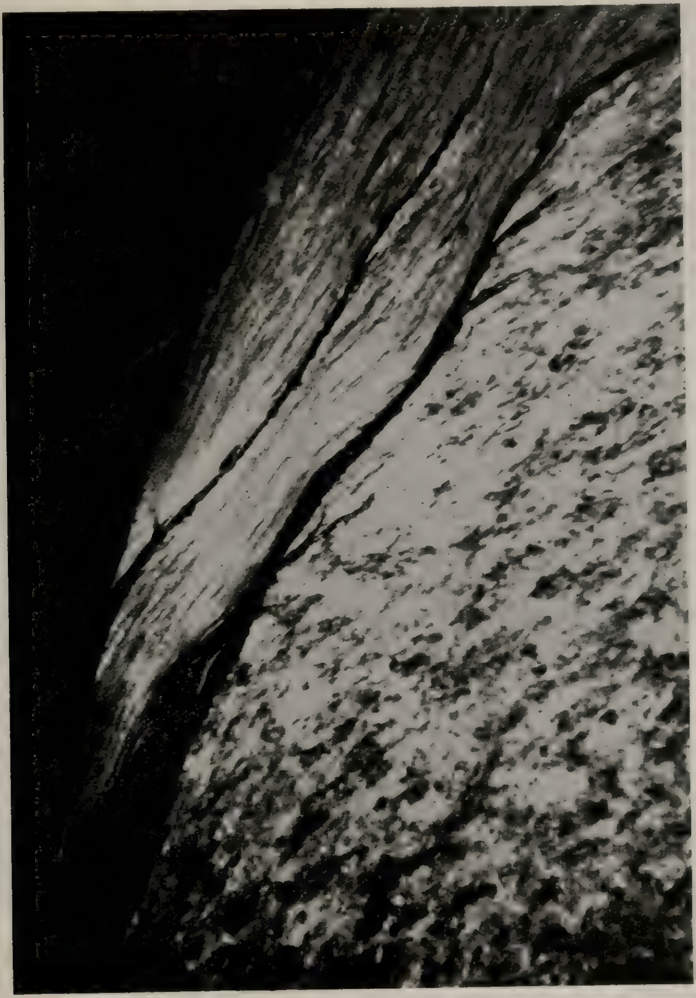

Fig. 5. Photomicrograph of Cross-Section of Gage Corner of Rail.
Magnification 40 X. Lightly etched in two percent Nital.
Shows fold of flowed metal and a shorter crack in the flowed metal.

That is, it seems highly probable that the starting point of the fracture was not far below the tread of the rail or possibly at the surface; in any event well above the zone where shatter cracks are found and probably in the metal affected by such surface conditions as burns or flowed metal.

Etch tests of slices from the rail showed no evidence of shatter cracks. However, they did show very severe flow of metal on the gage side of the upper corner of the head of the rail, and "wheel burning" of the tread. These features are shown in Fig. 4.

To see whether this flow of metal had caused cracks in the unbroken portion of the rail, which cracks might start spreading fatigue cracks, a transverse specimen was cut from this corner and prepared for microscopic examination. Fig. 5 shows a micrograph

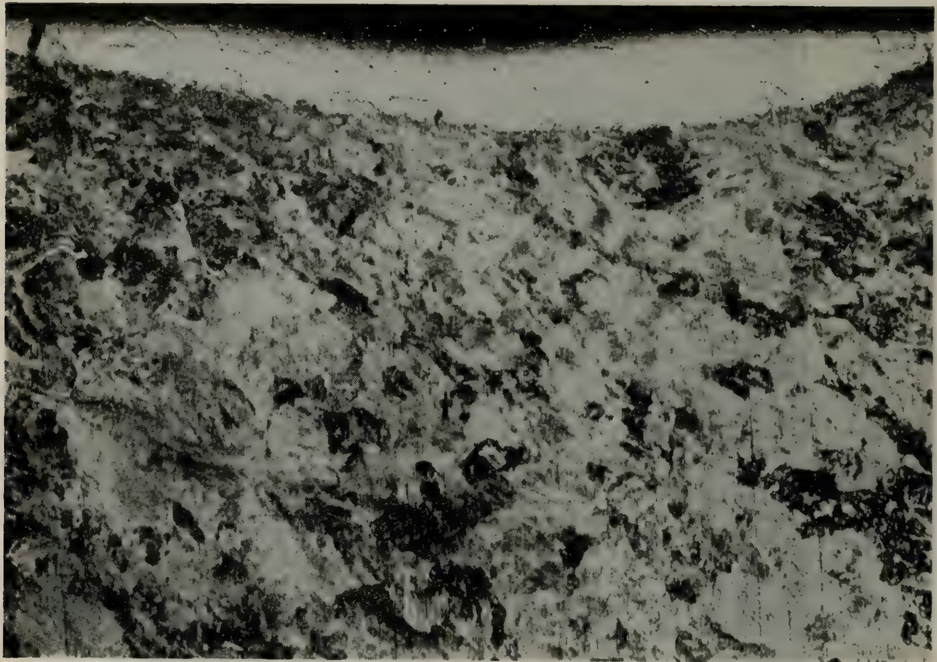

Fig. 6. Photomicrograph of Cross-Section of "Wheel Burned" Streak.
Magnification 150 X. Lightly etched with two percent Nital.
The area which remains light was hardened by the "wheel burn".
See Fig. 7 for further details of this area.

of the folded metal at the corner of the rail. A rather large fold is evident, and the upper dark line appears to be a crack in the severely cold-worked or flowed metal. It would seem quite possible that some such fold or crack in the missing piece of rail might have acted as a starting point for a horizontal spreading fracture which, as it spread, turned downward across the rail, as shown in Fig. 3.

It is also possible that the fracture may have started in the streak of wheel-burned metal on the middle of the tread as shown in Fig. 4. Such failures, although not common, have occurred in service. Transverse and longitudinal sections were cut through the wheel-burned streak on the Louisville & Nashville rail and Fig. 6 shows a micrograph of the wheel-burned metal. The white area of this micrograph represents metal which has been heated to above the critical range of the steel, 1,330 deg. F., by the friction of the wheel. Being a thin layer it is quickly quenched or hardened by the mass of the rail. The short lines in the white area are not cracks but are the ferrite grain boundaries originally present in the decarburized surface of the rail. Similar white lines marking ferrite boundaries can be seen just below the white area. Such hard material may either develop quenching cracks during this treatment or from subsequent wheel loads as shown in the deep-etched section of Fig. 4, and also in the micrograph of Fig. 7. It was necessary to magnify the cracks above 1,000 X to see them in this material. Several cracks were located on the section shown at 150 X in Fig. 6. It therefore seems reasonable to suspect that the horizontal portion of the fracture could have started from one of these cracks.

It is unfortunate that the second piece of the broken rail is not available, but the absence of shatter cracks as shown by etch tests, the absence of nucleus in the fractured surface available, the apparent starting point of the fracture close to the tread of the rail above the shatter-crack zone, the cracks developed in the flowed metal, and the presence of wheel-burns from which a fracture might start—all these items make it seem that this failure should not be considered as a transverse fissure; nor should it be regarded as a case of the failure of the control-cooling process to eliminate the shatter cracks which are the usual cause of internal fissures.

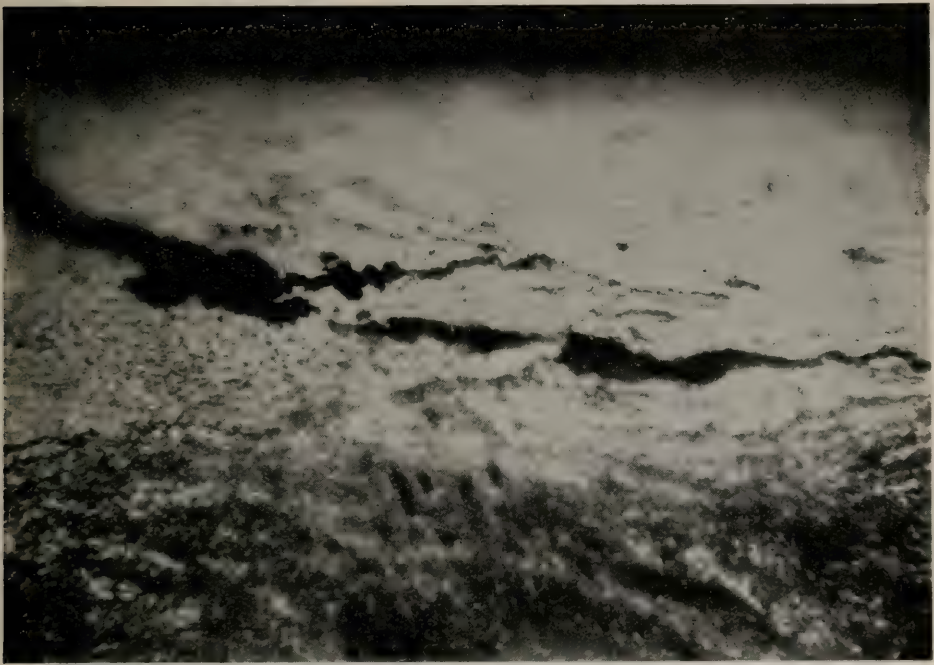

Fig. 7. Photomicrograph of One of Several Cracks Found in the "Wheel Burned" Area.
Magnification 1,500 *X*. Lightly etched two percent Nital.
Top surface of specimen rounded in polishing and out of focus.

Rail Failures on the Pennsylvania Railroad and on the Baltimore and Ohio Railroad.—A failure of a control-cooled rail was reported by Mr. W. D. Wiggins, chief engineer, Pennsylvania Railroad. A six-inch section of this rail was sliced and etched and found to be free of shatter cracks. Professor H. F. Moore examined the fissure in the Altoona laboratory. Fig. 8 (a) is a photograph of the fracture copied from one furnished by the Pennsylvania Railroad laboratories. This fracture apparently started from either a large inclusion or an aggregation of inclusions rather close to the tread of the rail, quite out of the zone where shatter cracks usually occur. This rail was rolled in October, 1936, Heat No. 82169-E-1. The failure of this rail is quite similar to the failure of a control-cooled rail from the Baltimore & Ohio Railroad, and the two will be discussed together. The Baltimore & Ohio rail was sent to the test party by Mr. P. Petri, chief engineer maintenance, in November, 1939. It was rolled in May, 1936, Heat No. 86190-E-7.

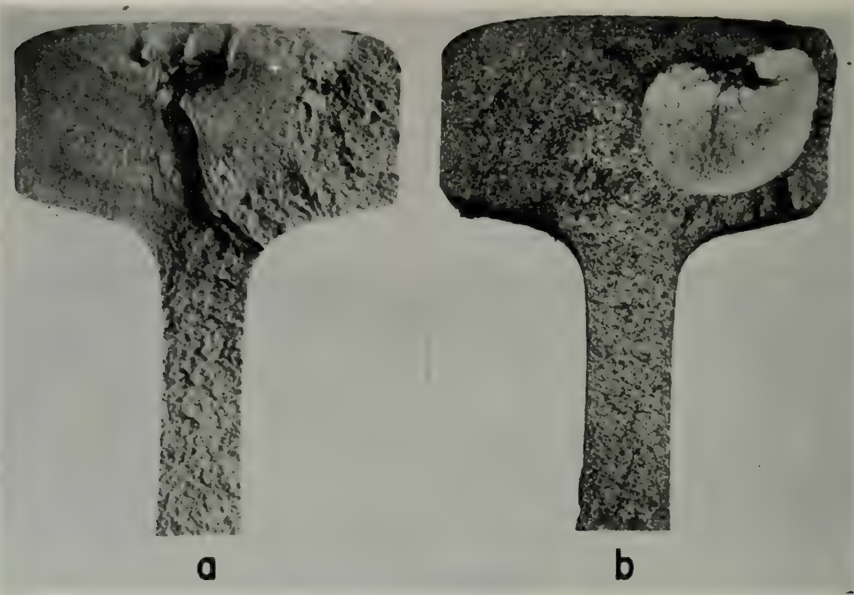

Fig. 8. Fissures Developed in Service.
(a) Rail from the Pennsylvania Railroad.
(b) Rail from Baltimore & Ohio Railroad.

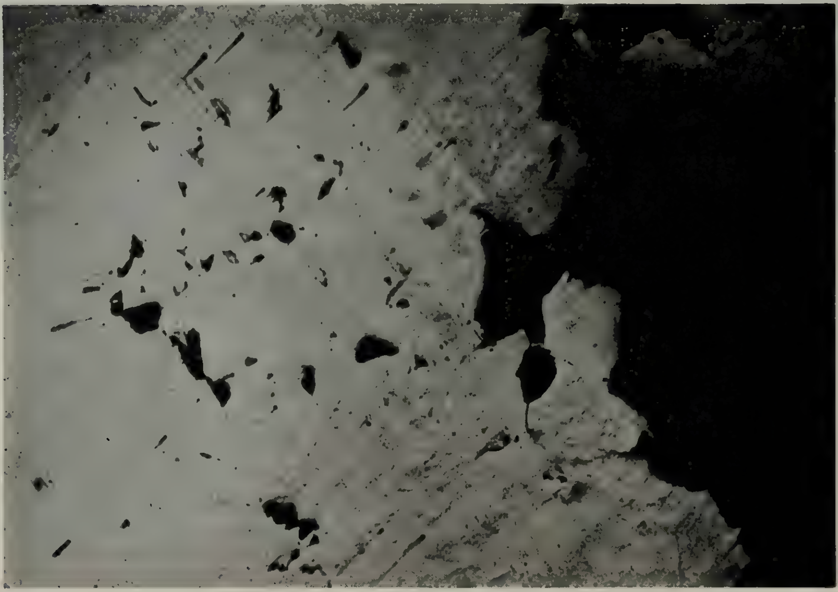

Fig. 9. Photomicrograph of Inclusions at End of Horizontal Portion of Fissures in Baltimore & Ohio Rail.
Magnification 67 X. No etch.

Fig. 8 (b) shows the fracture. Six-inch sections were cut from both sides of the fissure and were sliced and etched for shatter cracks but *no shatter cracks were found*. Careful examination of the apparent nucleus of the fissure shows that it started as a horizontal-longitudinal crack about ⅛ in. long and $\frac{1}{16}$ in. wide, then turned into a transverse fissure. A specimen was cut from one face of the fissure and polished close to the plane of the longitudinal portion of the fissure. When examined with the microscope the inclusions shown in Fig. 9 at 67 X magnification were found at the end of the horizontal portion of the fissure. At higher magnification it is possible to see several very fine cracks connecting these inclusions. These inclusions are about ½ in. below the tread of the rail where shearing stresses would be rather high, and are above the zone where shatter cracks are usually found, so it may be presumed that the cracks between the inclusions are other fatigue cracks.

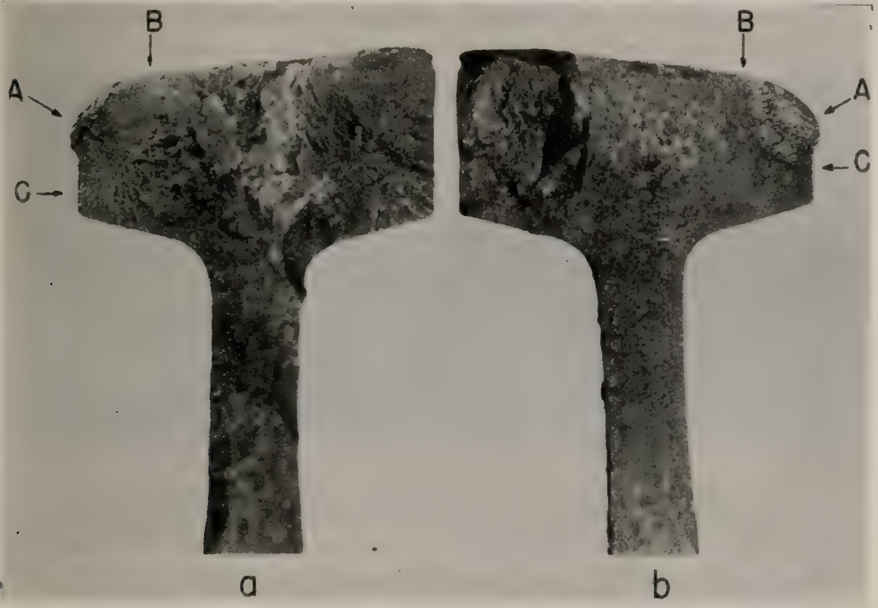

Fig. 10. Double Failure in Rail from Nickel Plate Road.
(a) Fracture at one end of fragment.
(b) Fracture at opposite end of fragment.

It is not possible to say definitely that the fissures in these two rails developed from the effect of wheel loads on the aggregation of inclusions at this point, but in any event this unusual aggregation of inclusions seems to be a probable factor in causing the fissure. The control-cooled process could not be expected to prevent any damage which might be due to the unusual aggregation of inclusions.

Rail Failure on the Nickel Plate Railroad.—A 112-lb. control-cooled rail in service on the Nickel Plate Railroad near Lafayette, Ind. failed by two fractures which were reported as transverse fissures.

This rail was sent to the test party by Mr. J. C. Wallace, assistant chief engineer and Fig. 10 (a) and (b) show photographs from the opposite ends of the piece which fractured out. Fig. 10 (a) shows a battered region near the center of the head which at first glance looks something like a transverse fissure. However, a closer study shows a progressive failure, starting from the gage corner of the rail at A in Fig. 10 (a) and (b), and spreading until it has covered the area bounded by the region B-C. From these photographs it is obvious that this rail had been badly worn, and a lip had been formed on the gage side. In some places, in the piece sent to the test party, this lip had been worn off.

Fig. 11 shows an etched section of the tread of this rail near one fracture. It shows a wheel-burned area containing many head checks. It would seem that the failures outlined by A, B and C in Fig. 10 represent the spreading of these checks to fatigue fractures.

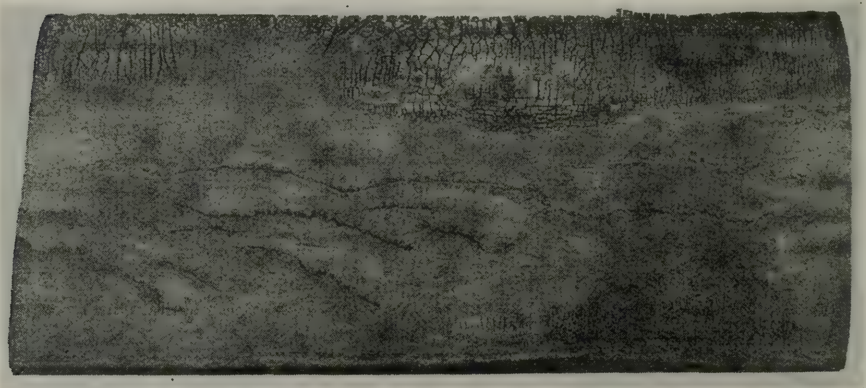

Fig. 11. Burn and Head Checks on Failed Rail from Nickel Plate Railroad. Specimen etched in Hot 50 percent Hydrochloric acid.

A six-inch section of the head was sliced horizontally and the slices etched in acid but no shatter cracks were found. These failures then do not seem to be transverse fissures starting from an interior defect, but rather progressive fractures starting from head checks in a wheel-burned area or at a very badly worn corner of the rail.

4. **Summary of Control-Cooled Rail Failures to Date.**—So far, the control-cooled rails which have failed in service or have given evidence of failure, and which have been sent to the laboratory for examination, do not show a single case of a fissure, transverse or otherwise, starting from shatter cracks. The rails reported by the Pennsylvania Railroad and by the Baltimore & Ohio Railroad do show transverse fissures starting, apparently from quite abnormal inclusions. So far, none of these rails can be regarded as failures of the control-cooling process to prevent transverse fissures. The control-cooling process is supposed to inhibit the formation of shatter cracks, and no one of these rails shows any evidence of shatter cracks. The control-cooled process does not by itself render a rail especially resistant to wear, batter or damage from head checks arising from such wear or from burns.

III. Control-Cooling Tests

By R. E. Cramer, E. C. Bast and N. J. Alleman

5. **Desirability of Changing Recommended Practice for Control Cooling Rails.**—The recommended practice for control cooling of rails which now serves as a basis of accepted practice, was written in 1937. Since that time improvements have been suggested in this practice, some of them as a result of the studies made by the Rails Investigation of the time and temperature in control cooling. The method of such tests has been described in detail in the Fifth Progress Report and the tests on individual rail specimens cooled at measured rates have given grounds for feeling that the present recommended practice is rather conservative so long as the rails actually cool no faster than the allowable maximum rate throughout the cooling container.

As is pointed out in Chapter II, no transverse fissure failures starting from shatter cracks have been found as yet in the control-cooled rails which have failed in service or in which defects have been shown by the detector car tests. However, as will be described in succeeding paragraphs, it has been found that under some conditions certain rails in mill cooling boxes cool much more rapidly than the rails in the middle of the pile, where the control thermocouple is placed in accordance with recommended practice. In any event it seems that control cooling, as practiced today, may be expected to cool satisfactorily all rails except the bottom layer and perhaps the layer next to the bottom. As will be seen from subsequent pages of this report, there is some evidence that even the bottom layers may be satisfactorily cooled in properly insulated containers.

6. **Control-Cooling Tests in Experimental Boxes to Establish Technique in Control Cooling of 131- and 112-lb. Rails.**—Tests have been made at Mill F, Mill D, and the Dominion Steel and Coal Corporation. These tests consisted of cutting one rail into 13 or more pieces about two feet long at the hot saws and cooling 12 pieces separately in small boxes packed with varying amounts of rock wool insulation, while one specimen was cooled in air as a control specimen to determine the tendency of that rail to develop shatter cracks. It is necessary to work with rails which have never cooled to room temperature because shatter cracks form only during the first cooling of the rail and at a temperature in the neighborhood of 200 deg. F.* for carbon steel rails. Mr. E. F. Kenney, metallurgical engineer of the Bethlehem Steel Company, has shown the members of the Rails Investigation test data which demonstrate that shatter cracks form at a considerably higher temperature in intermediate manganese steel rails, probably in the range 500 to 600 deg. F.

All together over 400 specimens have been cooled in this manner and tested for shatter cracks at the University laboratory. Over half of the ingots from which the rails were rolled were treated with hydrogen† to insure the presence of many shatter cracks in the air-cooled specimens.

The specimens used in the last two tests, completed in December, 1939, were removed from the boxes at various temperatures and cooled to 100 deg. F. under a three-foot mill fan then placed in ice water for eight hours to represent the fastest cooling a rail might experience when being removed from mill cooling containers in zero weather. Fig. 12 shows cooling curves for one test, together with the etch test results for the various specimens. It will be noted that specimen No. 1, removed from the cooling box after three hours and cooled under the fan and in ice water, developed more

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* Wishart and Swanson—"Methods of Preventing Shatter Cracks or Flakes in Carbon Steels", Trans. ASM, September, 1939, footnote bottom of page 785.

† Method described in AREA Proceedings, Vol. 40, 1939, p. 658 and Reprint No. 14 of Engineering Experiment Station, University of Illinois.

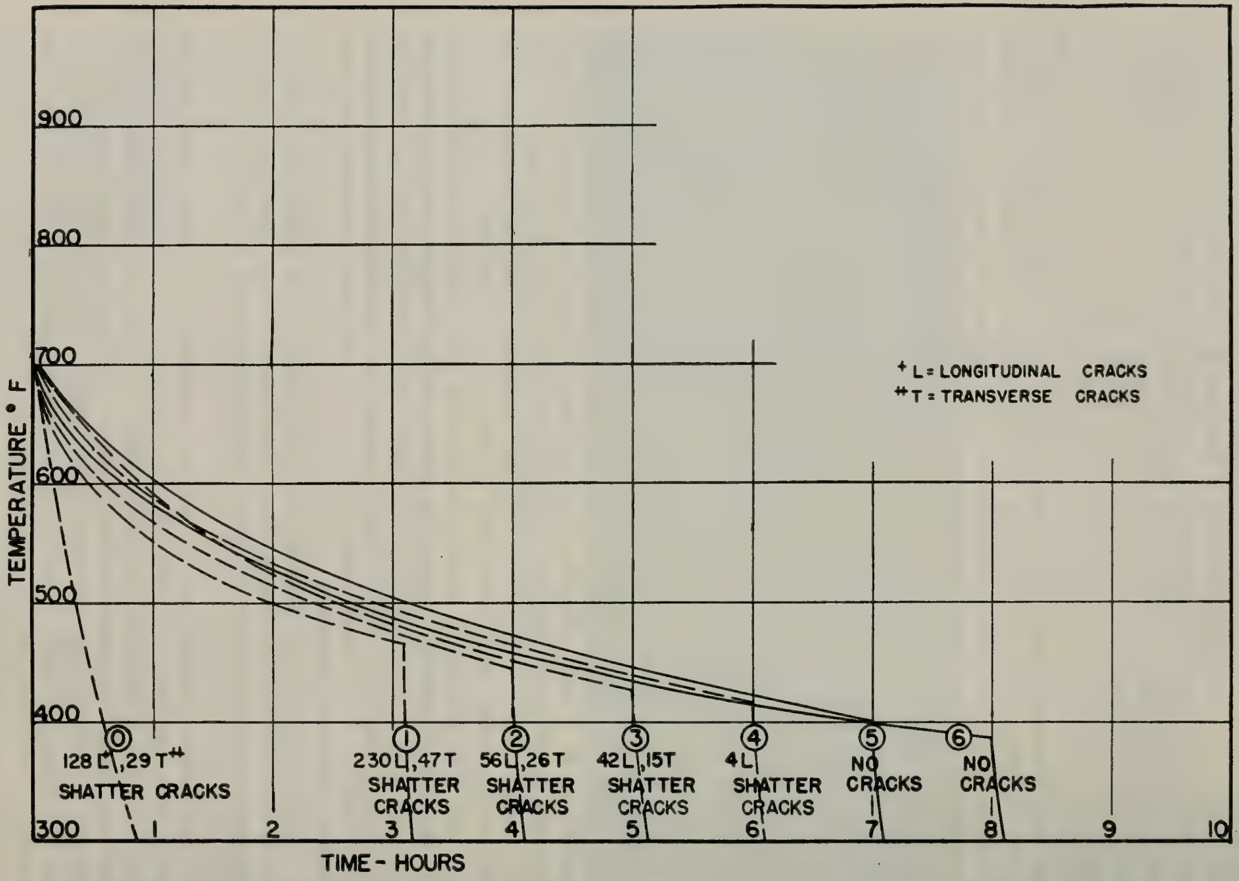

Fig. 12. Controlled Cooling Tests.—Ingot Treated with Hydrogen Test No. 10. Heat 40159, Ingot 4, Rail 4, Sec. 131-lb. Chem. Anal. C. 0.75; Mn. 0.82; P. 0.014; S. 0.022; Si. 0.18. Ingot treated with 32 cu. ft. of Hydrogen.

shatter cracks than specimen No. 0, cooled from the rolling heat in air in approximately one hour.

It was necessary to hold the rails in the boxes one hour longer to prevent the formation of shatter cracks when the specimens were cooled under the fan and in ice water after removal from the cooling boxes than was the case for any previous tests in which the specimens were cooled in still air after removal from the cooling boxes.

The conclusion from all these tests was that seven hours was the maximum time required to cool from 700 deg. to 300 deg. F. in order to prevent the formation of shatter cracks in rails even from hydrogen-treated ingots and that the sudden cooling of rails upon removal from the containers after seven hours did not produce shatter cracks.

TABLE 1

RESULTS OF ETCH TESTS OF SPECIMENS HELD FOR VARIOUS LENGTHS OF TIME AT FOUR DIFFERENT TEMPERATURES

Constant Furnace Temperatures	*Time in Furnace, Hours*	*†Number of Shatter Cracks on One Side of Six-inch Slice*			
		Test 1	*Test 2*	*Test 3**	*Test 4**
Control Spec.*	0	105 L, 45 T			
1,100° F.	1	65 L, 24 T			
"	2	5 L,			
"	3	0			
"	4	0			
"	5	0			
"	6	0			
Control Spec.*	0	160 L, 44 T	87 L, 18 T	92 L, 62 T	125 L, 50 T
900° F.	1	86 L, 14 T	26 L, 4 T	191 L, 78 T	160 L, 50 T
"	2	55 L, 8 T	8 L,	43 L, 21 T	163 L, 44 T
"	3	3 L, 2 T	0	8 L, 1 T	14 L, 3 T
"	4	0	0	0	0
"	5	0	0	0	0
"	6	0	0	0	0
Control Spec.*	0	116 L, 19 T	118 L, 21 T		
700° F.	1	85 L, 8 T	94 L, 10 T		
"	2	14 L,	29 L, 1 T		
"	3	1 L,	4 L,		
"	4	0	0		
"	5	0	0		
"	6	0	0		
Control Spec.*	0	139 L, 46 T			
500° F.	1	138 L, 57 T			
"	2	52 L, 28 T			
"	3	44 L, 5 T			
"	4	10 L, 1 T			
"	5	0			
"	6	0			

* Control specimen cooled in air outside the mill.

† Shatter cracks are recorded as the number of longitudinal (L) or transverse (T) shatter cracks on one side of a longitudinal slice six inches long.

** For Tests 3 and 4, after the specimens were removed from the furnace they were cooled under a mill fan and then in ice water for eight hours.

7. **Tests of Holding Rails at Constant Temperatures.**—Another type of test which has been made gives information on the time necessary to hold rails at various constant temperatures to prevent the formation of shatter cracks. These tests were all made at the Gary mill of the Carnegie–Illinois Steel Corporation on 131-lb. rails and are comparable with those reported by Wishart and Swanson (see previous reference) on 112-lb. rails. After the hydrogen-treated specimens were cut at the hot saws they were cooled on the mill floor to temperatures of 1,100, 900, 700 and 500 deg. F. and all but the control specimen were placed in a gas-fired furnace held at the above temperatures. The results of these tests are summarized in Table 1.

After being removed from the furnace the specimens from Tests 3 and 4 were cooled under the mill fan and then in ice water for eight hours. This accounts for the increased number of shatter cracks in the specimen held in the furnace one hour as compared with the number found in the control specimen cooled on the mill floor. It will be noted that the formation of shatter cracks was prevented by holding the specimens three hours at 1,100 deg. F.; four hours at 900 deg. and 700 deg. F., and five hours at 500 deg. F. The tests also furnish evidence that after the rails have been held a sufficient time at a given temperature, fast cooling to freezing temperatures is not dangerous.

8. **Tests of the Cooling of Rails in Mill Containers.**—Tests of a third type were conducted at seven of the American steel mills making railroad rails. They consisted of determining the actual time of cooling of rails in the mill cooling containers.

Twelve thermocouples are attached one foot from the end and at the middle of six rails in each container as indicated on the sketches of Figs. 13 to 20, inclusive. Time and temperatures are recorded for about 20 hours after the boxes are loaded. The curves given in Figs. 13 to 20 show results obtained for the fastest cooling box at each mill. Considerable variation was found between the four tests made at each mill. Tests made at two different dates are included for Mill E because the boxes were insulated in the interval between the two tests.

The length of time required, after charging, for the fastest cooling and slowest cooling portion of the rails to reach a temperature of 300 deg. F. for all tests is given in Table 2.

It will be noted from Table 2 that the ends of some rails in the bottom tier in the containers at four mills have cooled to 300 deg. F. in less than seven hours. The reason for this at Mill F is that two boxes are being loaded at the same time. Usually three tiers are placed in one box then three in the other box. The probable reason that the ends of the rails at Mill E cool faster is that the boxes were built to hold 45-ft. rails which leaves over three feet of empty space at each end of 39-ft. rails. The circulation of air in this space may cause fast cooling of the ends of the rails. The addition of double walls with granulated slag insulation between the walls made a considerable difference between two of the tests made at Mill E in January, 1940, and those of January, 1939. The one test at Mill C in which a rail cooled in 4½ hours represents one of four boxes along the roller line where a cool draft blows along one side of the boxes.

Table 2 also shows that 19 out of 26 containers required 20 hours or more for the slowest cooling rail to cool to 300 deg. F. Six out of the 26 required over 25 hours.

In the control-cooling tests which have been made in connection with the Rails Investigation, no shatter cracks have been found even in hydrogen-treated rails if the rail had remained seven hours or more in the cooling container *unless in that time it has cooled to below 300 deg. F.* In the mill cooling containers, after nine or ten hours most of the rails in the bottom layer have cooled down to 300 deg. F. or lower. It seems important that no rail in the cooling container should cool down to 300 deg. F.

TABLE 2

TIME REQUIRED FOR RAILS TO COOL TO 300 DEG. F.

Results given based on tests in control-cooling containers at mills, and show the time required for the fastest-cooling and slowest-cooling rails to reach 300° F.

Date	Mill	Rail Section, lb. yd.	Box or Car	No. of Rails per Charge	Air Temp. F.	Fastest-Cooling Position		Slowest-Cooling Position	
						Time, hrs. to 300° F.	Couple No.†	Time, hrs. to 300° F.	Couple No.†
Cars and Boxes With Less Than 100 Rails									
Jan. 3, '39	D	131	Car	75	50°	10¼	9	20	8
Feb. 7, '39	D	131	Car	75	38°	9¼	9	22	8
Feb. 8, '39	D	131	Car	75	37°	6½	9	18	8
April 25, '39	B	131	Car	88	78°	12¾	1	28	8
April 25, '39	B	131	Car	88	78°	13	9	30	8
Jan. 24, '39	E	131	Box	90	20°	3¼	1	16¼	8
Jan. 25, '39	E	131	Box	90	15°	3½	1	16¼	12
Jan.†† 29, '40	E	112	Box	99	22°–28°	Couples 1 & 3 broke		21	12
Jan.†† 29, '40	E	112	Box	99	22°–28°	6	3	20	12
Boxes With More Than 100 Rails									
March* 2, '39	I	131	Box	150	47°	9½	1	24	12
March 3, '39	I	131	Box	150	50°	7	1	22	8
March** 3, '39	I	131	Box	150	46°	7½	1	19	8
Jan. 3, '40	C	112	Box	126	30°	11¾	1	27	8
Jan. 3, '40	C	112	Box	132	30°	11	1	22	8
Jan. 5, '40	C	131	Box	130	20°	4½	1	27	8
Jan. 5, '40	C	131	Box	130	20°	12	1	28	8
Jan. 17, '40	F	110	Box	212	40°–60°	1½	1	26	8
Jan. 18, '40	F	112	Box	140	2°–33°	2½	3	17½	8
Jan. 19, '40	F	112	Box	189	3°–20°	2½	1	22	8
Jan. 20, '40	F	112	Box	203	8°–20°	2¼	1	25	8
Jan.†† 31, '40	E	112	Box	121	24°–34°	2½	1	19½	12
Jan.†† 31, '40	E	112	Box	119	24°–34°	7½	1	17½	8
Feb.‡ 13, '40	G	112	Box	150	17°–22°	11	1	23	8
Feb.‡ 13, '40	G	112	Box	150	17°–22°	9½	1	22	8
Feb.‡ 14, '40	G	112	Box	150	10°–18°	10½	1	21	8
Feb.‡ 21, '40	G	127	Box	117	18°–26°	9	1	23	8

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† The couple number indicates the position in the cooling containers as indicated in the sketches, Figs. 13 to 20, inclusive.

* Box insulated with two inches of rock wool three feet high completely around bottom of box.

** Box insulated with four inches of rock wool six feet high across the ends and extending four feet along sides from the ends.

†† A double wall with granulated slag insulation between had been added since the tests on January 24 and 25, 1939.

‡ Box insulated with 4 in. of insulating brick 26 in. high completely around bottom of box.

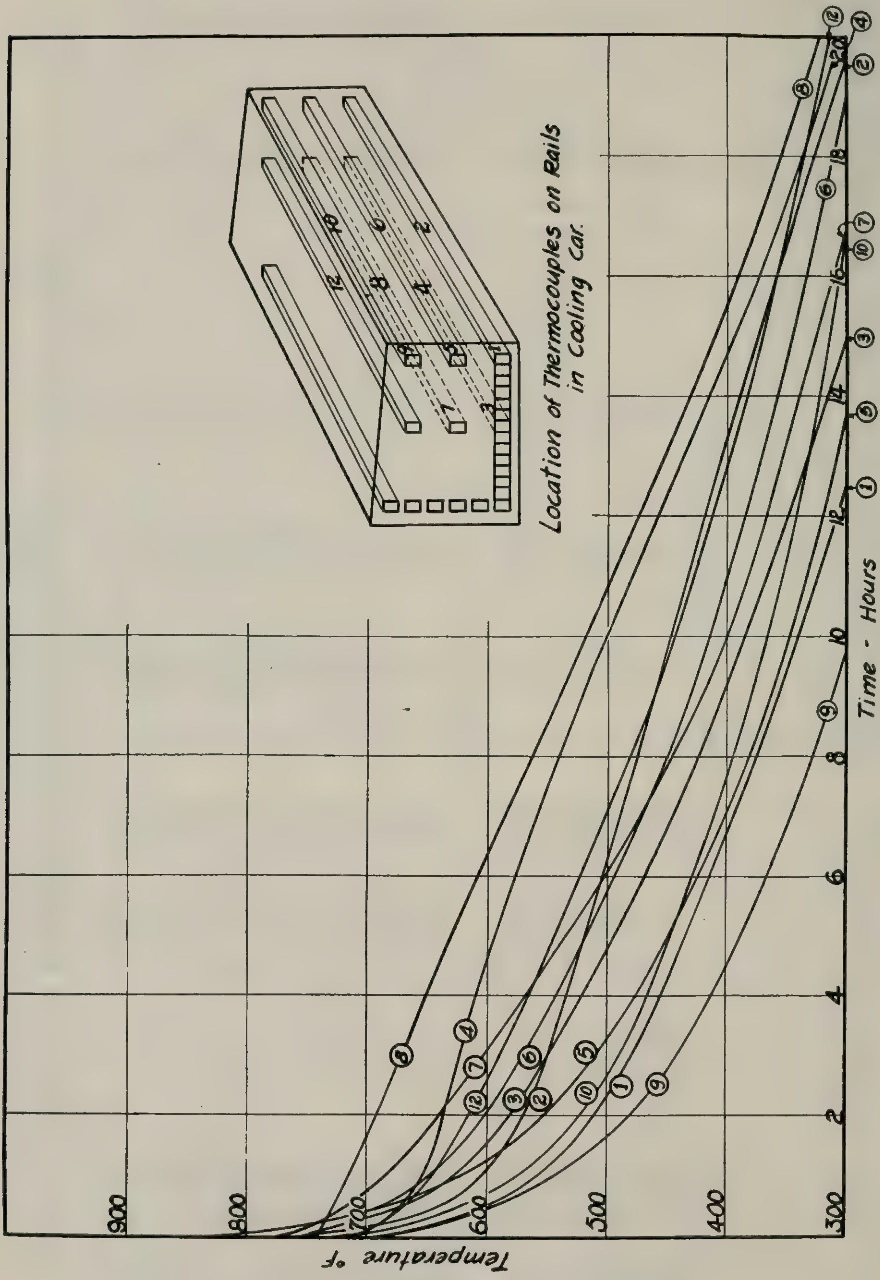


Fig. 13. Controlled Cooling Curves from Rails Mill D, Test 2.
Cooling Car No. 30343; 131-lb. section. Air temp. 38 deg. F. February 7, 1939.

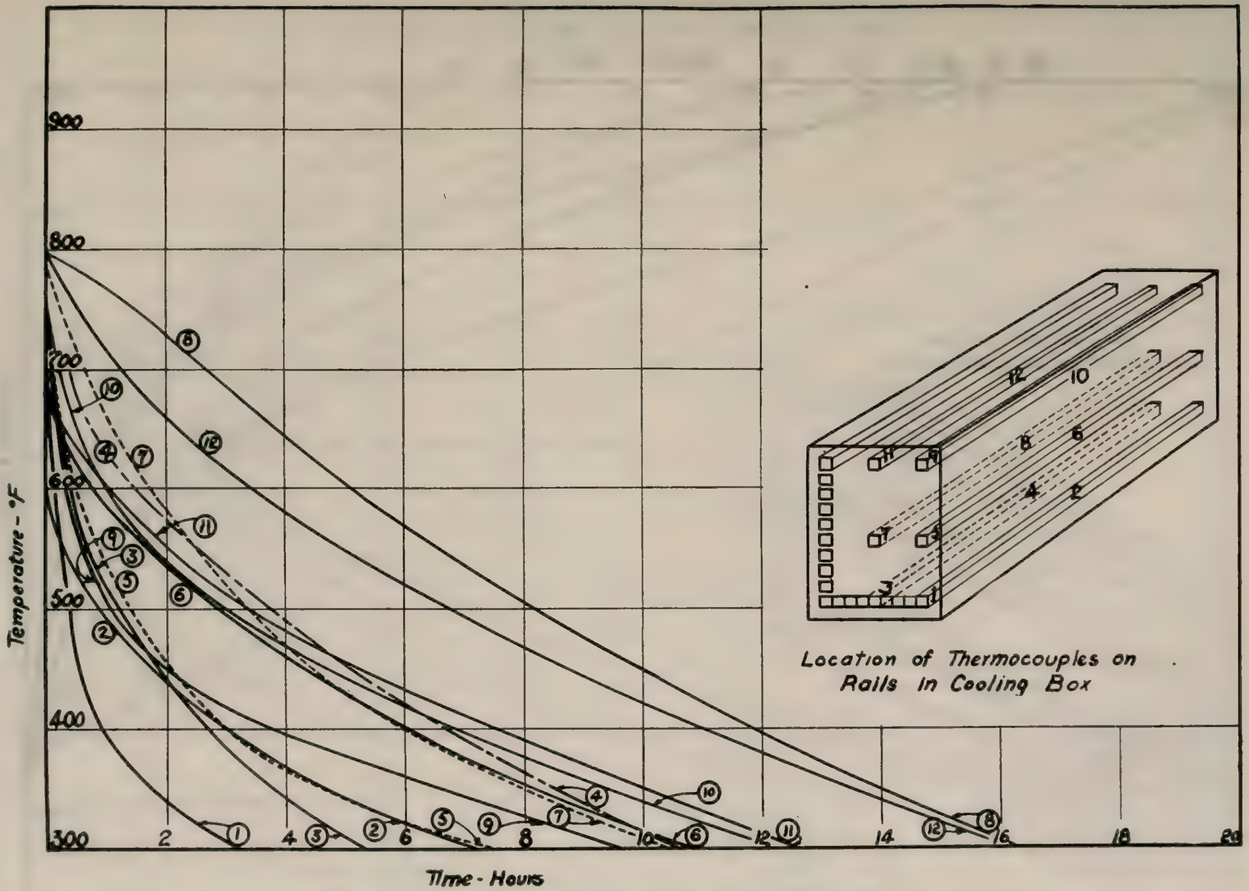


Fig. 14. Controlled Cooling Curves from Rails Mill E, Test 1.

Cooling Box No. 14. 131-lb section. Air temp. 20 deg. F. January 24, 1939.

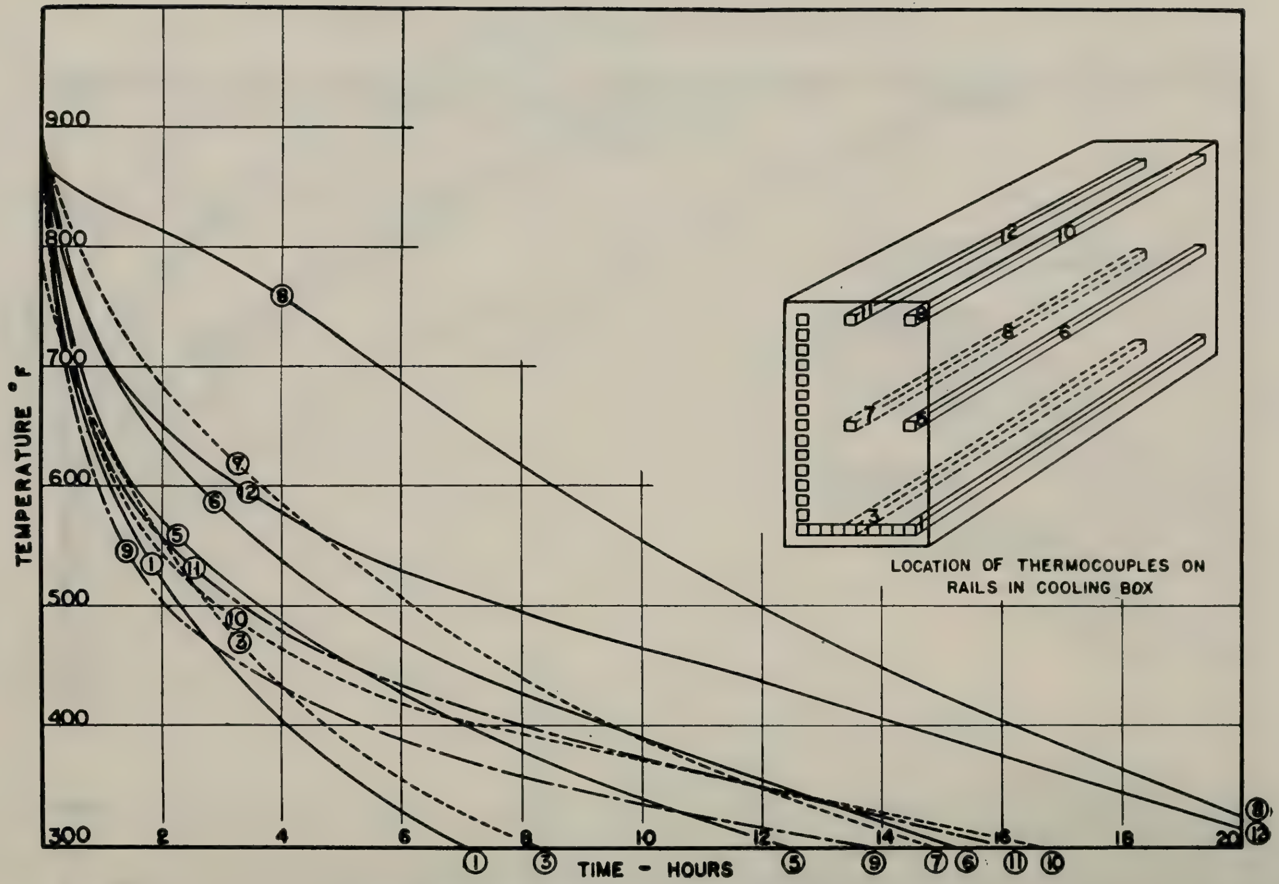


Fig. 15. Controlled Cooling Curves from Rails Mill I, Test 2.
Cooling Box No. 7. 131-lb. section. Air temp. 50 deg. F. March 3, 1939.

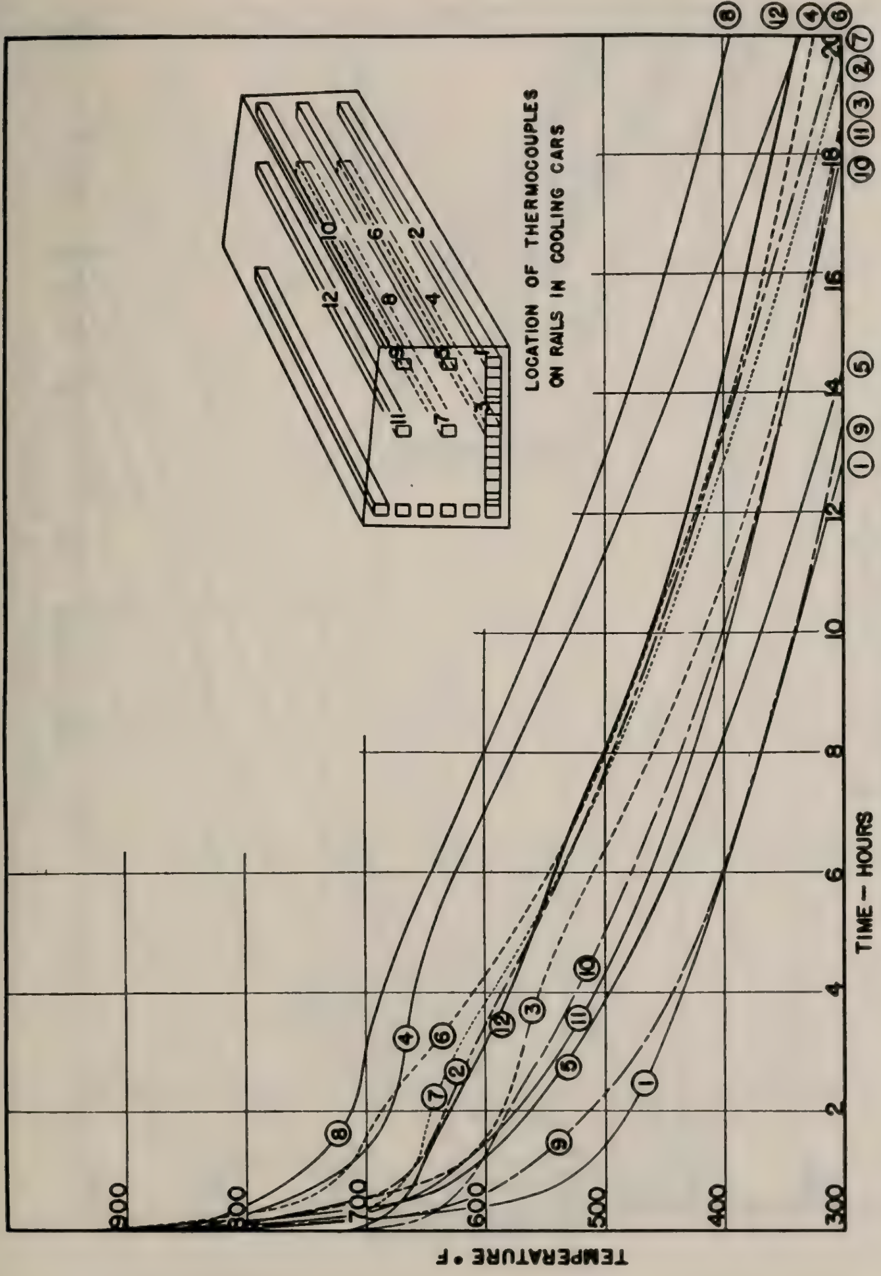


Fig. 16. Controlled Cooling Curves from Rails Mill B, Test 1.
Cooling Car No. 13418. 131-lb. section. Air temp. 78 deg. F. April 25, 1939.

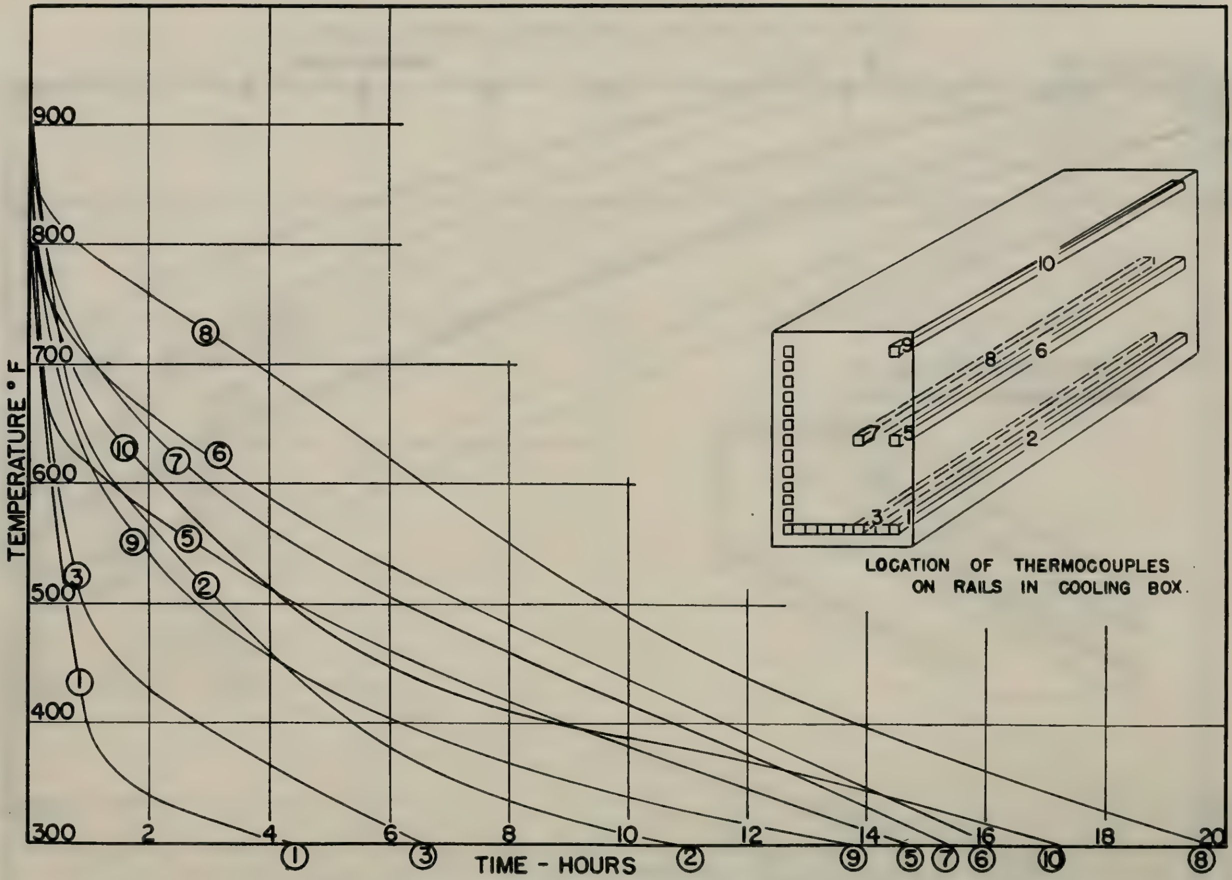


Fig. 17. Controlled Cooling Curves from Rails Mill C, Test 3.
Cooling Box No. 12. 131-lb. section. Air temp. 20 deg. F. January 5, 1940.

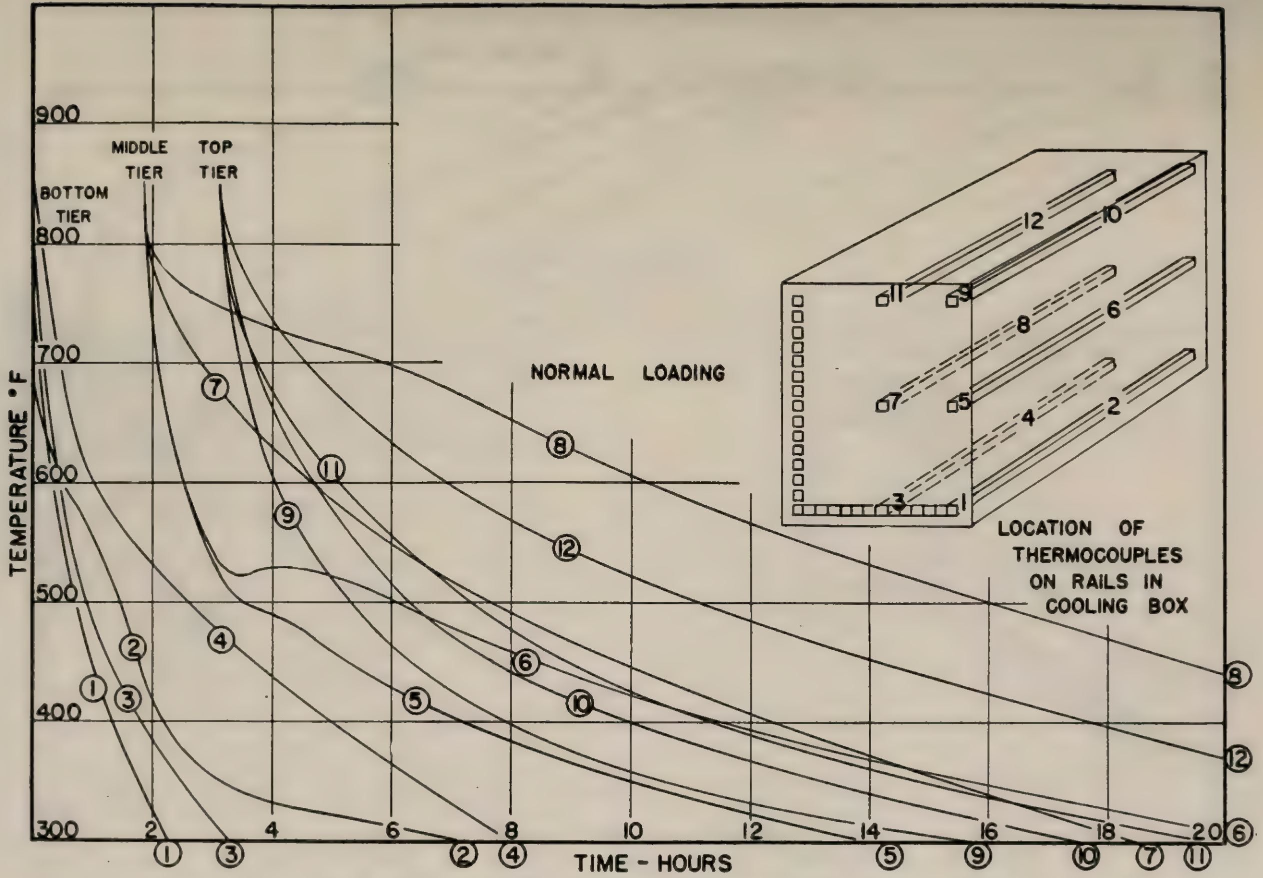


Fig. 18. Controlled Cooling Curves from Rails Mill F, Test 5.
Cooling Box No. 9. 112-lb. section. Air temp. 8–20 deg. F. January 20, 1940.

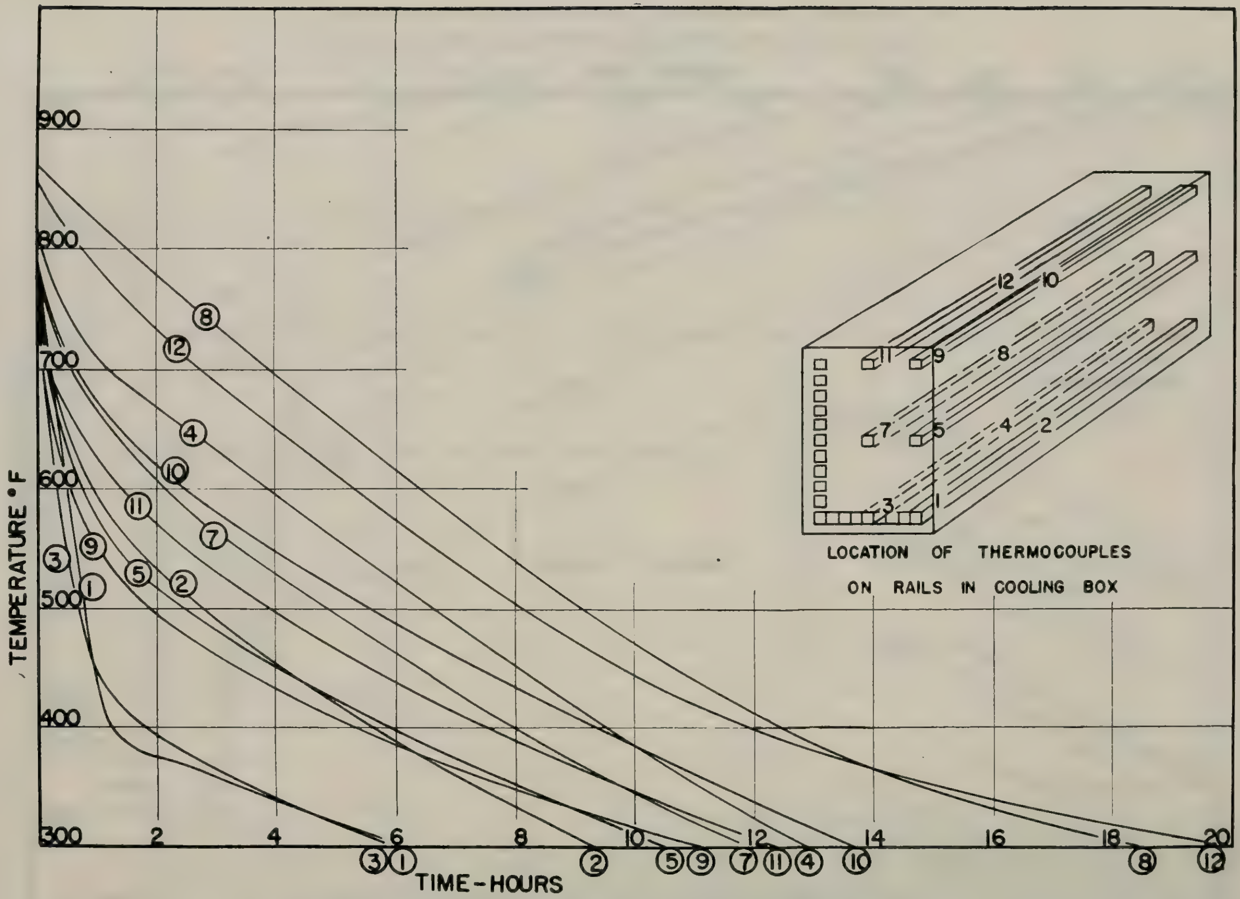


Fig. 19. Controlled Cooling Curves from Rails Mill E, Test 4.

Cooling Box No. 12. 112-lb. section. Air temp. 22–28 deg. F. January 29, 1940.

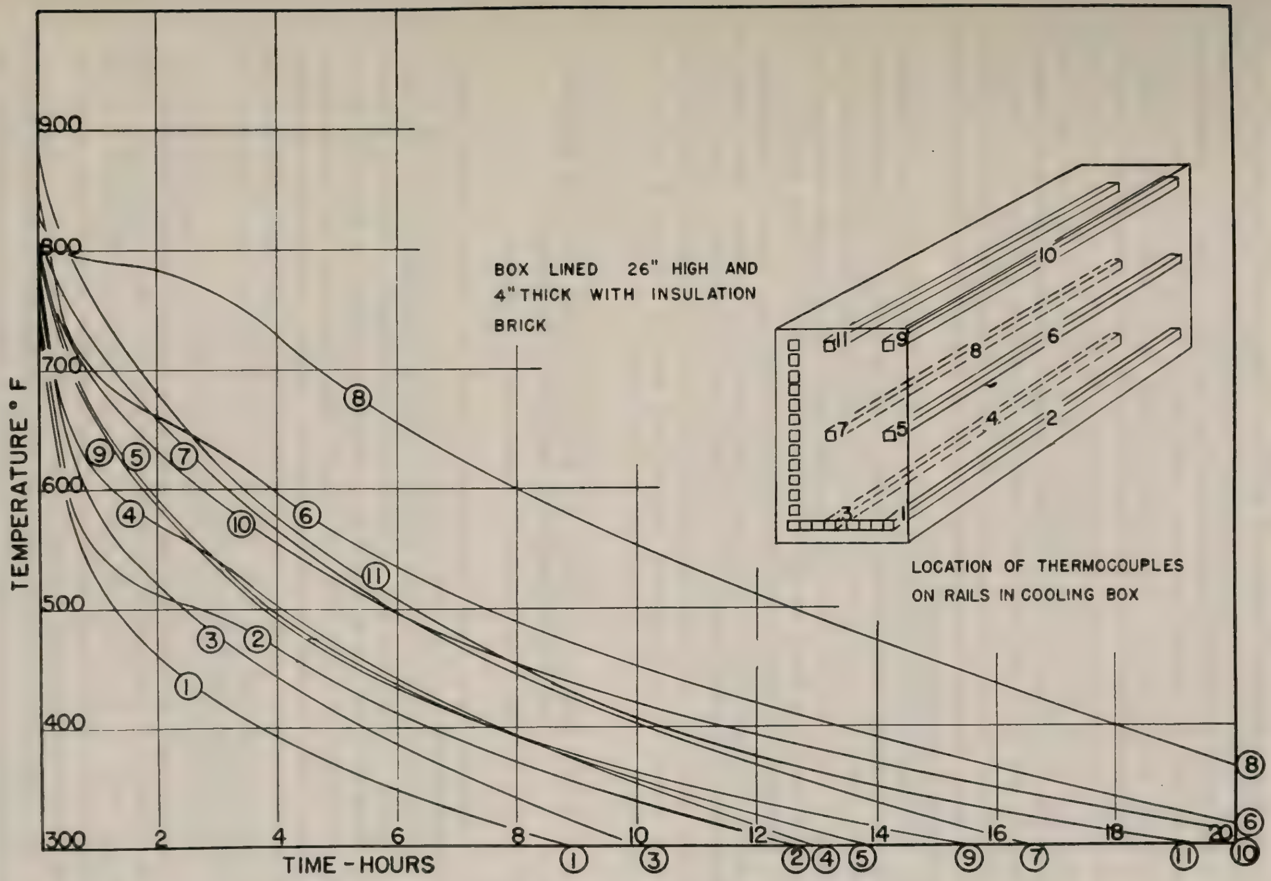


Fig. 20. Controlled Cooling Curves from Rails Mill G, Test 5.
Cooling Box No. 13. 127-lb. section. Air temp. 18–26 deg. F. February 21, 1940.

in less than seven hours, and if only seven hours is required to prevent shatter cracks then it seems unnecessary to keep the lid on the container until the center rail of the pile cools to 300 deg. F. The present practice of keeping the rails in the container until the center rail of the pile has cooled down to 300 deg. F. seems to impose an unnecessary delay in removing the slower cooling rails, while it does not insure that the lower row of rails will cool slowly enough to inhibit the formation of shatter cracks.

Tests results indicate that if the present practice (which prohibits the removal of rails from the container until the center rail of the pile cools to 300 deg. F.) were changed to permit the removal of the lids of the containers after 12 hours, there would be no danger of shatter cracks in the slowly cooling rails, while the likelihood of shatter cracks in any rails which may cool rapidly in the containers would not be changed. The optimum time for the removal of rails from the boxes will depend not only on the likelihood of shatter cracks, but also on the ease of handling and liability of warping of the rails as they are being removed.

The improvement in the second series of tests at Mill E, after better insulation had been installed in the cooling containers, and the results of the cooling tests at Mill G, where the containers were insulated with especial thoroughness,—these give ground for hope that by the use of insulation alone even the fastest cooling rail in a container may cool slowly enough to inhibit the formation of shatter cracks.

The change, suggested above, in the present requirements for control cooling would facilitate experimentation—which is very much needed—on insulation, baffle plates, or other means of retarding cooling of the rails first placed in the container. There is reason to hope that such experimentation carried out at each mill will give assurance that the fastest cooling rail in a container will not cool down to 300 deg. F. in less than seven hours.

IV. Field Tests for Batter of End-Hardened Rails in Service on the Chesapeake and Ohio Railroad

By H. R. Thomas, J. L. Bisesi and N. J. Alleman

9. **Description of Test Location and Tests.**—In the Fifth Progress Report of this investigation there was presented a brief outline of the proposed program of tests of end-hardened rails in the tracks of the Chesapeake & Ohio Railroad near Carey, Ohio. The purpose of these tests was to determine the effectiveness of various processes of end hardening in reducing the batter of rail ends. It is hoped that these tests will also serve as a basis for determining the range of Brinell hardness which is effective in preventing batter without introducing danger of chipping, and will give information on the effect of joint conditions on batter. The actual laying of these rails was begun April 6, 1939, and was completed April 10, 1939. The tests are now in progress, and three sets of observations have been made.

The test rails were laid in the northbound track (westbound, time table direction), starting two miles northwest of Carey approximately 1,870 ft. south of Milepost C 76. This location was chosen because, extending northwest from the starting point, there is tangent, relatively level track, subjected to heavy coal traffic. Nine lots of 100 rails each are laid, south to north, in the order shown in Table 3, which gives a brief description of the end-hardening processes used.

The original plan for the tests provided that measurements of batter and hardness should be made on the test rails: (1) at the time of laying, (2) one month later after the track had been resurfaced, (3) three months after laying, (4) six months after laying, and at intervals of six months thereafter.

TABLE 3

DESCRIPTION OF END-HARDENED TEST RAILS, LISTED IN ORDER OF LAYING*

Process No.	*Description*
	FIELD-HARDENED RAILS
7	Oxy-acetylene heating; quenched by adjacent cold metal. To insure uniform hardening the mill scale was removed by grinding.
9	Oxy-acetylene heating, using a free-held torch; quenched by sprinkling with a measured amount of water—then tempered.
10a, Hard	Oxy-acetylene heating, water quench, all operations controlled by machine. Of the two lots of rails hardened by this machine, these rails were treated to have the greater hardness. Most of these rails were retreated in October to reduce the hardness.
	Non-hardened rails for comparison.
10b, Soft	This is the softer of the two lots of rails hardened by this process.
	All of the above field-hardened rails were rolled by Mill E.
	MILL-HARDENED RAILS
2	Gas heating; compressed-air quench. (Mill E.)
3	Water-quench from the rolling heat. (Mill I).
1	Teleweld induction heating; water quench. (Mill B).
6	Quenched by compressed air on removal from the Brunorizing furnace. (Mill D).

* A more complete description of the end-hardening processes will be found in the Fourth Progress Report of the Joint Investigation of Fissures in Railroad Rails, AREA, Proc. Vol. 39, 1938, p. 812.

10. **First Series of Tests.**—Members of the test party of the investigation were present during and immediately after the laying of the test rails, and obtained the following measurements:

1. Initial readings with a 10-inch AREA type batter gage on all joints. Measurement of joint gaps were also made.
2. Cross-sections of about 10 percent of the rail heads, using the Pennsylvania Railroad's cross-section recorder. These records will permit determining rail wear under traffic.
3. Brinell hardness measurements on the hardened rail ends and also on the unhardened rails using the portable Brinell hardness tester described in the Fifth Progress Report.

Based on the readings taken with the 10-inch batter gage, a list of all joints having a difference in height between the leaving and the receiving rail of more than 0.01 in. was furnished to the representatives of the Chesapeake & Ohio Railroad, and these joints were ground off to bring both rail ends to approximately the same level. Out of the 900 test joints some 220 were so ground before the second series of field measurements was made.

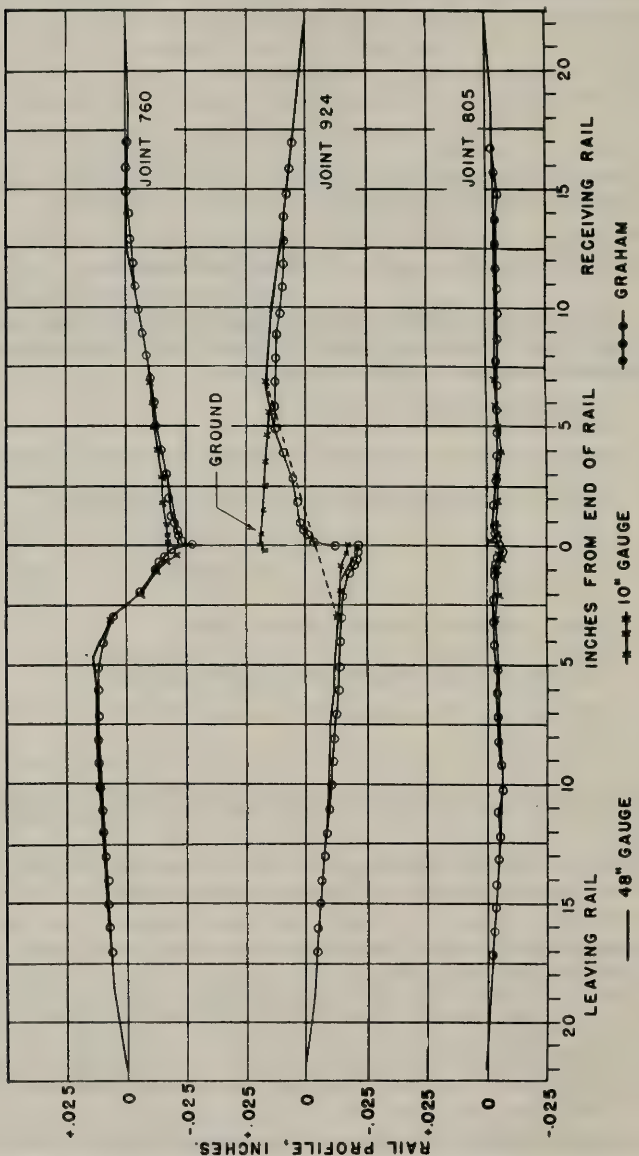


Fig. 21. Joint Profiles (Vertical) End-Hardened Rails.

Showing examples of extreme joint conditions and comparison of the three methods of measurement. Test Track, Chesapeake & Ohio Railway, Carey, Ohio.

The hardness results obtained in April, 1939, were from Brinell indentations measured on the top of the rail after filing a flat spot only deep enough to remove mill scale. That is, these hardness values were undoubtedly affected by any decarburization of the steel at and immediately below the tread of the rail. For the purpose of these service tests, however, it was deemed desirable to obtain hardness measurements on the actual top of the rail, without grinding so deeply as to remove decarburized metal, since the hardness of the surface metal will undoubtedly be a factor in the early stages of batter of rail ends.

11. **Second Series of Field Tests.**—Between the first and the second series of field tests the Chesapeake & Ohio section forces put the test track in good line and surface. Ties were replaced where needed and new ballast added. This work was completed about June 1, 1939. By this time 1,800,000 tons of traffic had passed over the test rails.

Due to the length of time required for the alinement and resurfacing of the test track, the original schedule of field tests was modified and the second series of measurements was made in June, 1939, soon after the track had been resurfaced. It was not thought necessary to repeat the measurements of the cross-section of rail heads after only two month's service. The vertical profiles near the ends of each test rail were taken with a 48-in. modified AREA batter gage and also with a Graham profile recorder. These are taken as the basic (or zero) readings. Brinell hardness tests were made on about 25 percent of the rail ends. An attempt was made to get Brinell readings on the same rails as those tested in April, but it was found that due to the creep of rails it was not possible to do so in all cases.

12. **Third Series of Field Tests.**—The third series of measurements was made in October, 1939, at which time the rails had been in service for a period of six months and had carried a total of 21,500,000 tons of traffic. The second series of measurements had been made so near to three months after the laying of the rail that it seemed unnecessary to make any three-months measurements. The readings taken in October included vertical profile measurements with the 48-in. gage on all joints and Brinell hardness readings on approximately 50 percent of the joints.

A change which will affect some of the results of the tests is the rehardening of some of the joints field hardened by Process 10. Two groups of rails end hardened by this process have been previously listed: (1) Process 10b, Soft, (averaging 349 Brinell in the April tests), and (2) Process 10a, Hard, (averaging 485 Brinell in the April tests). Before the October measurements were made it was decided that the rails of the group known as Process 10a, Hard, were so hard that it was feared that the rail ends might chip under heavy traffic. Consequently most of these rail ends were rehardened using the same equipment as before, but so adjusted as to produce approximately the same range of hardness as the group known as Process 10b, Soft. Sixteen of the original 100 Process 10a, Hard, joints were left at their original hardness. It will be interesting to watch the effect of this second heat treatment on the batter of the rail ends as indicated by the measurements of the profile of the rail and on the effect of work hardening as indicated by the Brinell hardness.

13. **Measurements for Batter.**—The data taken for the determination of batter in the April, June, and October series of tests have been compiled and profiles for a few of the joints which have been plotted are shown in Figs. 21-23, inclusive. The vertical scale of these profiles is greatly exaggerated relative to the horizontal scale (horizontal distance). The profiles plotted were chosen not with the object of showing the

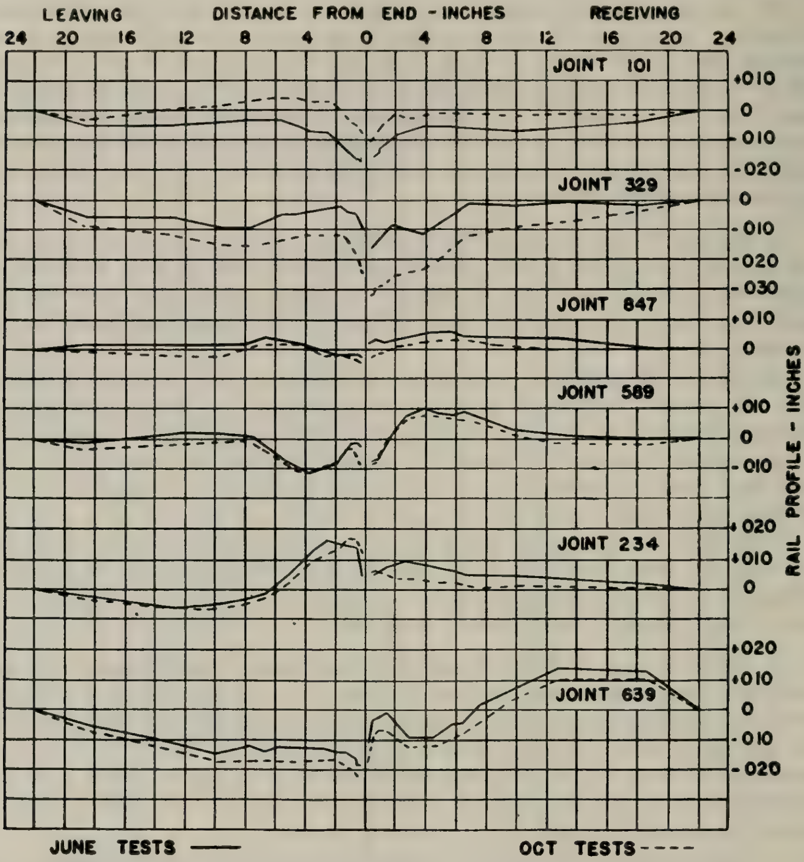


Fig. 22. Joint Profiles (Vertical) End-Hardened Rails.
Showing examples of extreme joint conditions, using 48-inch batter gage. Test Track, Chesapeake & Ohio Railway, Carey, Ohio.

characteristic features of any one hardening process, but rather to illustrate *extreme cases* of some of the conditions found in the various joints. It should be pointed out that the vertical distances in Figs. 22 and 23 have been drawn to a scale of 25 to 1, whereas the horizontal distances are plotted to a scale of 1 to 3. As a consequence the irregularities of the top of the rail and of the joints are greatly exaggerated.

The curves in Fig. 21 drawn from data obtained in April with the 10-inch AREA type gage are shown by crosses on full lines. The other profile diagrams were drawn from the readings taken in June with the Graham profile recorder and the 48-in. batter gage. In Figs. 22 and 23 all the profile diagrams were drawn from data taken with the 48-in. batter gage. The profile diagrams drawn from measurements made in June, 1939, after the track had been lined and surfaced will be used as the basic profiles from which the determinations of future batter will be made. In Figs. 22 and 23 the profiles for the June tests are shown in solid lines and those for the October readings in broken lines.

The profiles shown in Fig. 21 were intentionally drawn to a large vertical scale (50 to 1) to show the comparative results obtained with the three types of batter gage used. It will be noted that in all cases the profiles obtained by the use of the Graham profile recorder agree very closely with those obtained by the use of the 48-in. gage and that, for two of the profiles, the profiles obtained by the use of the 10-in. gage agree with the other two. The profiles shown in Figs. 21, 22 and 23 are so plotted that at points away from the end of the rail (out of the "batter zone") any general wear of rail is eliminated from consideration.

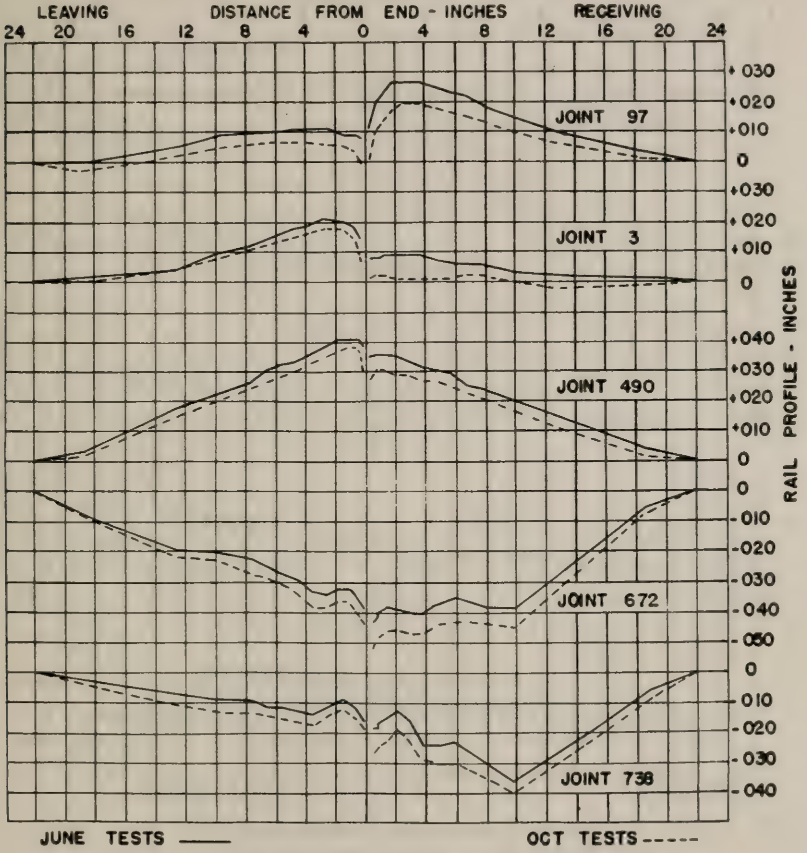


Fig. 23. Joint Profiles (Vertical) End-Hardened Rails.
Showing examples of extreme joint conditions, using 48-inch batter gage. Test Track, Chesapeake & Ohio Railway, Carey, Ohio.

The third profile shown in Fig. 21, that for Joint No. 924, illustrates how profiles based on 10-in. gage readings might indicate that a joint was level, when in reality it was not. This is evident if the broken line between the two end readings of the 10-in. gage is considered to be the zero line.

In view of the fact that the use of the 48-in. gage determines profiles which agree very closely with those determined with the Graham profile recorder, that readings of the 48-in. gage are easier to obtain and to compare than are readings of the Graham profile recorder, and that profiles determined from readings of the 48-in. gage are not subject to the misleading indication found in some profiles determined from readings of the 10-in. gage,—in view of these reasons it is planned to make all future measurements of batter with the 48-in. gage.

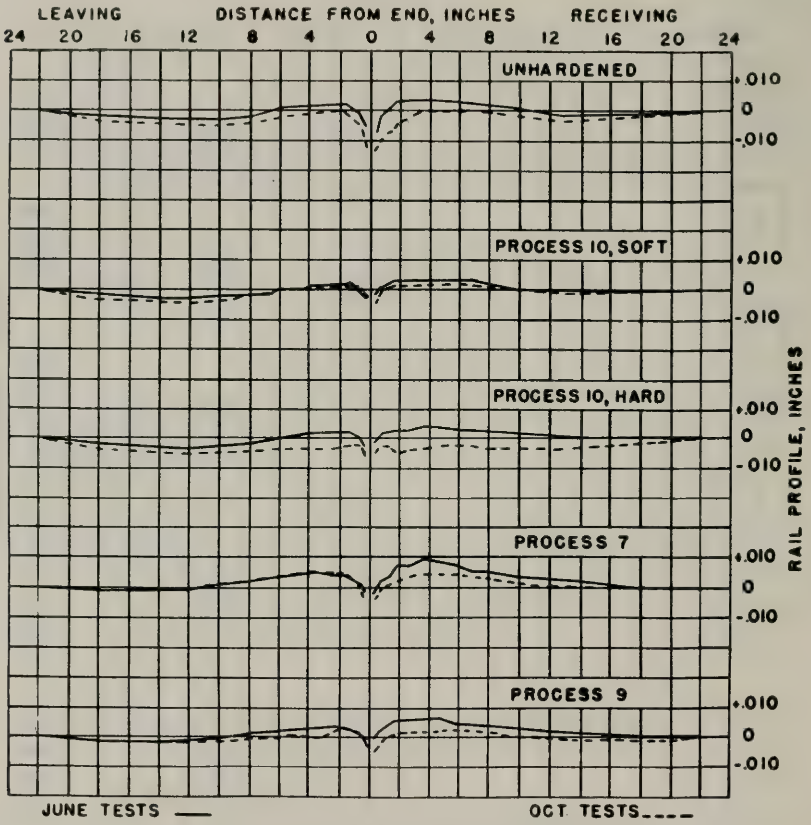


Fig. 24. Average Joint Profiles (Vertical).

Field end-hardening processes, using 48-inch batter gage. Test Track, Chesapeake & Ohio Railway, Carey, Ohio.

These values are the average obtained from 100 joints hardened by each process.

Examples of joints which are quite even and level are shown by profile 847, Fig. 22 and 805, Fig. 21. It may be seen that in neither case does the profile at any point between the supports of the 48-in. gage vary more than 0.01 in. from the level of the ends. On the other hand, certain other joints have a quite uneven profile, as indicated by curves 589, 234 and 639, Fig. 22. In all these cases the irregularities in the profile are apparently due to conditions existing previous to the time of the basic (June, 1939) series of tests, and the irregularities still persist after 21,500,000 tons of traffic had passed over the rail.

Cases in which one rail in a joint is higher than the other are shown in Fig. 21, Joint 760 and in Fig. 23, Joint 3 (leaving rail high) and in Fig. 21, Joint 924 and Fig. 23, Joint 97 (receiving rail high). It should be noted that Joints 3 and 97 were ground before hardening in order to remove mill scale and obtain more uniform hardening results. Joint 924 furnishes an illustration of the hump which is frequently left near the end of a rail after grinding.

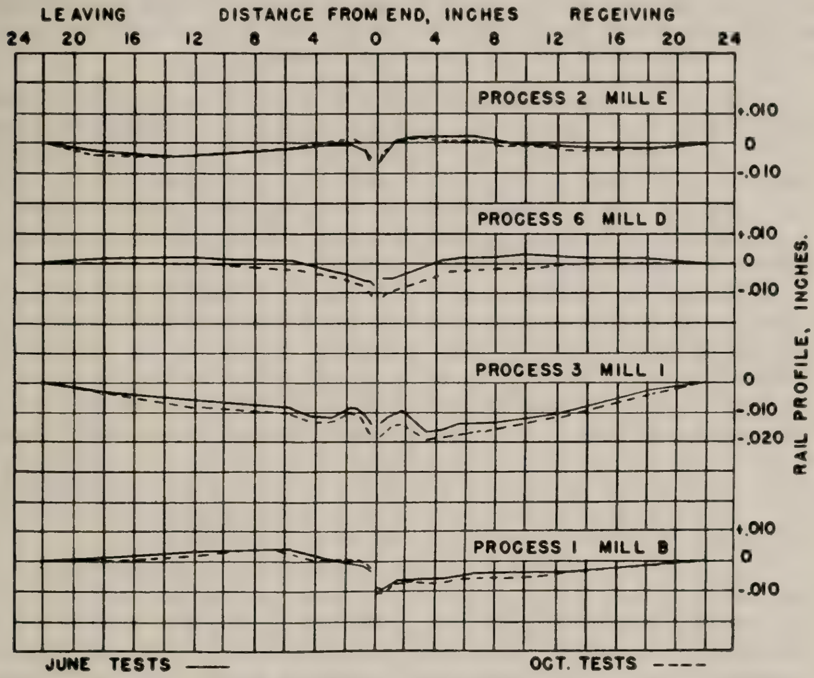


Fig. 25. Average Joint Profiles (Vertical).
Mill end-hardening processes, using 48-inch batter gage. Test Track, Chesapeake & Ohio Railway, Carey, Ohio.
These values are the average obtained from 100 joints hardened by each process.

Fig. 23, Joints 490 and 672, furnish examples of high and low joints, respectively. Another example of a low joint is furnished by the profile for Joint 738, Fig. 23. In Joints 490 and 672 the rails themselves seem to be straight enough, but they slope so that they form high or low joints. However, in the case of Joint 738 the receiving rail is 0.025 in. higher at the end than it is 9 in. back from the end.

In most of the above mentioned examples it may be noted that the June and the October profiles are in close agreement. The curves for Joints 101 and 329, Fig. 22, show that there was a change of level of joint between the two successive measurements. The condition of Joint 101 seems to be improved whereas Joint 329 seems to be getting farther from the level joint condition that is desirable.

The average profile for all the rails end hardened by each process is shown in Figs. 24 and 25. In these figures, as in Figs. 22 and 23, the June readings are represented by full lines, and the October readings by broken lines.

In considering the various methods of interpreting batter, it was decided that, at least for the present, the following method is to be used: In using this method the data are obtained by means of a 48-in. gage, and a profile of the joint is drawn to some convenient scale. A line, representing a straight edge, is then drawn from the point representing the end of the gage through the high point on the profile. The vertical distance from this line to the rail at the end is used in determining the amount of batter of the end. The change in this vertical distance between the initial (or zero) readings and any successive reading will be taken as the actual batter of the end of the rail. A comparison of this vertical distance obtained from the June observations and the corresponding distance from the October observations indicate that there is very little batter even in the rails which were unhardened.

14. **Brinell Hardness Measurements.**—As mentioned previously, representative Brinell hardness measurements of rail ends were taken in April, immediately after the rails had been laid; in June, after the track had been resurfaced and had carried 1,800,000 tons of traffic; and in October after the rails had been in service for six months and had carried 21,500,000 tons of traffic. The April readings represent the hardness of the rail ends as the rails were laid, and the subsequent readings are affected by the cold working under traffic.

In the April tests the hardnesses were measured at a point ⅜ in. from the ends of the rails and on the center line. To avoid the previous Brinell impressions, in the June tests the measurements were made at the same distance from the ends, but ¼ in. toward the outside of the rail. Most of the readings in October were taken along the center line of the rail head and approximately ⅜ in. from the end of the rail as the Brinell impressions made in April were no longer visible. It was necessary to make certain that no October impressions were made in any of the April impressions. In making Brinell tests in April and in June it was necessary to file a small amount off of the tread of the rail in order to remove the scale. After six months of traffic, however, the rail surface was smooth enough that filing was unnecessary.

It should be stated *again* that this method of measuring hardness, in which only a small amount of metal is filed off at the point where the impression is to be made, is quite different from the procedure used in the mills in measuring hardnesses for the determination of acceptance under specifications. In the mills the decarburized surface is generally removed so that readings will be obtained on the metal below. However, it is felt that for the purpose of these field tests the hardness should be obtained for the actual running surface of the rail.

The Brinell machine as described in the Fifth Progress Report was originally designed to take readings on a rail end with the joint over the tie or midway between the ties. When the test rails were laid no attempt was made to spot the ties, consequently the number of rail ends on which the hardness could be taken was limited. In many cases the creep of the rails in track made it impossible to obtain readings on some rail ends on which readings had been taken before. Before the October tests were made, in order to overcome these difficulties new side bars and an additional pair of legs were designed and built to be substituted for the original setup. These new legs hook under the base of the rail directly under the Brinell ball. By using both sets of legs on the machine as was found necessary, approximately double the number of Brinell readings could be obtained.

A summary of the Brinell hardness results is given in Table 4, in which are included the number of readings taken, the range of hardness, and the average Brinell numbers for each group. As previously noted, all of the rail ends in the group designated as 10a, Hard, except those in 16 joints, have been re-treated so that their hardness fell in the same range as those in group 10b, Soft. Therefore, in the October test

TABLE 4

BRINELL HARDNESS NUMBERS AND RANGE OF HARDNESS FOR ALL END-HARDENING PROCESSES

	April			June			October		
	No. of Readings	*Range Brinell Hardness Number*	*Average Brinell Hardness Number*	*No. of Readings*	*Range Brinell Hardness Number*	*Average Brinell Hardness Number*	*No. of Readings*	*Range Brinell Hardness Number*	*Average Brinell Hardness Number*
Field-Hardening Methods									
Process 7	70	296–342	315	65	321–361	338	72	329–380	355
Process 10b, Soft	71	298–425	349	48	291–385	340	220	297–444	361
Process 10a, Hard	44	408–532	485	61	418–555	495	18*	454–560*	502*
Process 9	33	359–488	423	36	351–495	426	75	361–524	421
Mill-Hardening Methods									
Process 2, Mill E	48	282–340	314	53	291–357	329	128	302–396	346
Process 6, Mill D	44	305–359	333	49	326–387	352	113	338–393	365
Process 3, Mill I	49	351–402	373	52	358–420	383	114	347–418	379
Process 1, Mill B	38	321–450	409	50	336–477	419	110	323–470	411
Non-Hardened	76	234–261	246	51	241–277	255	94	256–295	273
Total Readings	473	-----	-----	465	-----	-----	944	-----	-----

In the April and October tests, hardnesses were measured approximately ⅜ in. from the ends and on the center line of the rail head. In the June tests, hardnesses were measured at ⅜ in. from the ends of the rail but ¼ in. outside of the center line.

* The readings in October for Process 10a, Hard, include only those taken on joints which had not been re-treated.

values listed in Table 4 the values under 10b, Soft, include the re-treated rail, while the values under 10a, Hard, are from the 16 joints not re-treated.

It is apparent from the table that, in general, there has been an increase in Brinell number under the work-hardening action of traffic. This *increase* is greater for the softer rails than for the harder. This is apparent not only from the average values but also from the range of hardness. In view of the fact that between June and October most of the rail ends in group 10a, Hard, were re-treated and softened, comparisons of work-hardening increase of hardness for this particular group are not advisable.

The results for the group of rails designated 10b, Soft, seem peculiar. Average Brinell numbers decreased between April and June, and increased between June and October. This result was found to be due to specially rapid quenching directly under the jets of cooling water, and the shifting of location of the Brinell impression across the head of the rail on successive series of tests. See Chapter V, page 717.

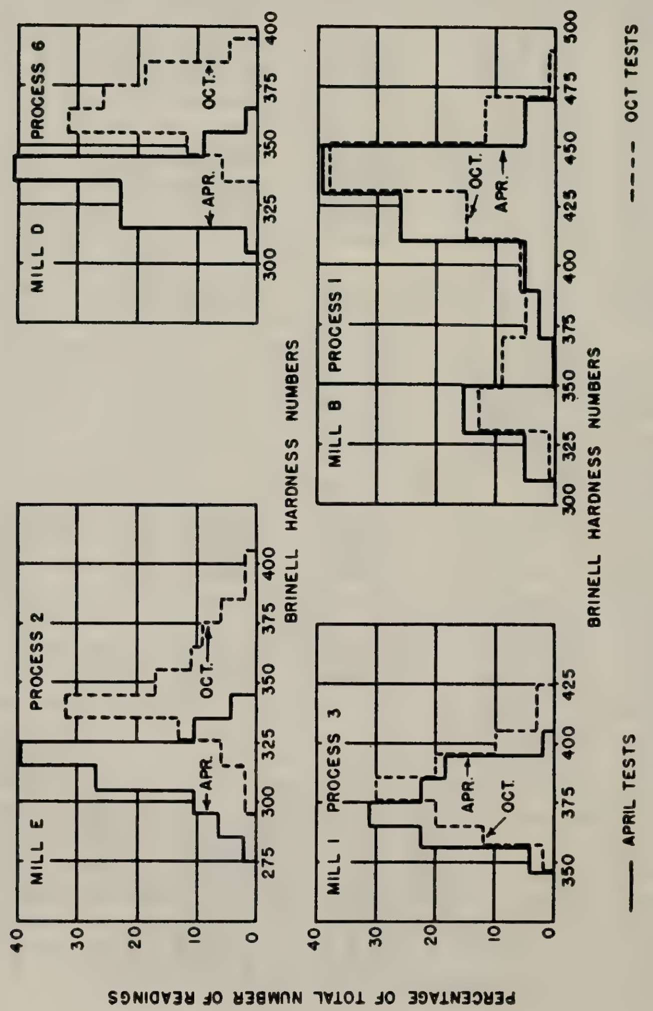


Fig. 26. Distribution of Brinell Hardness Numbers—Mill End-Hardening Processes.

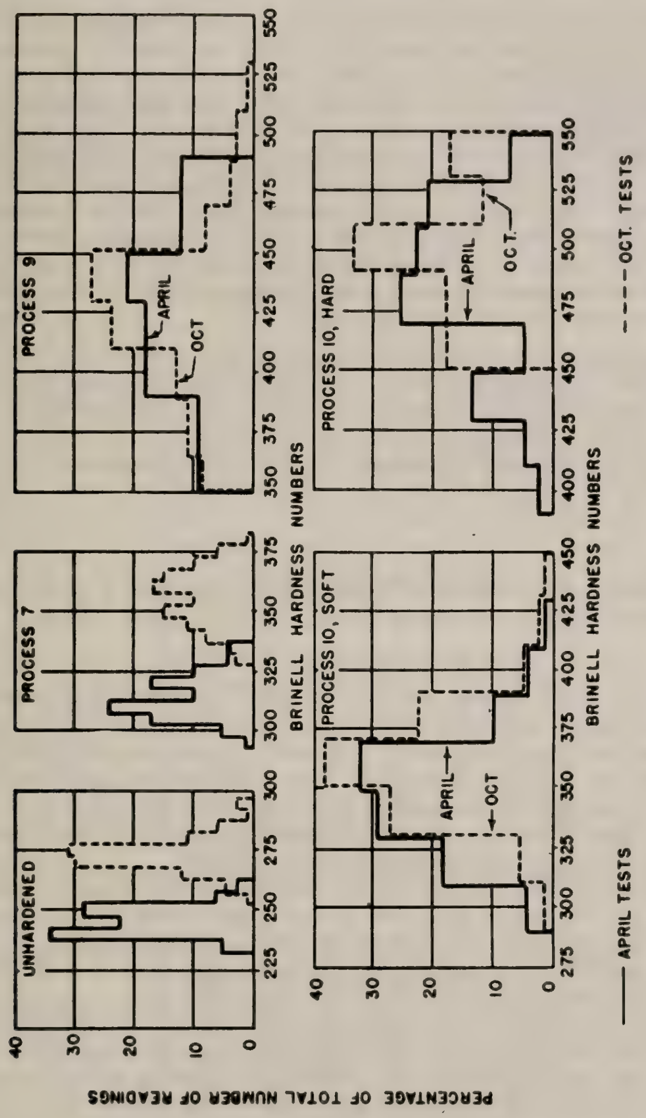


Fig. 27. Distribution of Brinell Hardness Numbers—Field End-Hardening Processes.

The distribution of Brinell hardness numbers for each process of mill-hardening for both the April and October tests is shown in Fig. 26 and the same information for the field-hardening methods is shown in Fig. 27. In these figures the values of the percentage are based on the total number of readings for each process. By this method of plotting it is possible to show, graphically for each process, the relative hardness, the range of hardness, and the shift in relative hardness due to the work-hardening of the top of the rail. In considering these figures it is pointed out again that the values shown for Process 10 are on the basis of the altered grouping of the rails hardened by this process. In the October tests the values indicated for Process 10a, Hard, are based on 18 readings which fell in this group, while the re-treated Process 10a, Hard, rails are included with the Process 10b, Soft, group.

It will be noted that the nine groups of test rails cover a wide range of Brinell hardness, the average ranging from 246 for the unhardened rails up to 485 for one of the field-hardening methods. These are the values obtained in April, while the values in June and October, after two and six months of traffic, were somewhat higher. This range of values should permit the determination of the effect of hardness on the amount of batter of end-hardened rails. There is also a considerable spread of values of hardness for each of the end-hardening processes. In most cases, however, there is less range of hardness in the rails end hardened at the mill than in those end hardened in the field, although this is not true in all cases.

15. **Conclusions.**—While the end-hardened test rails have not been in service long enough to show any appreciable batter, the data obtained do indicate that the 48-in. batter gage consistently gives comparative readings of the ordinates of the vertical profile from which the batter of the rail may be determined.

The data presented also demonstrate the feasibility of determining the changing Brinell hardness of the running surface near the end of the rail as traffic work hardens the steel.

V. Metallographic Tests in Connection with the Field Tests of End-Hardened Rails in Service on the C. & O.

By R. E. Cramer and E. C. Bast

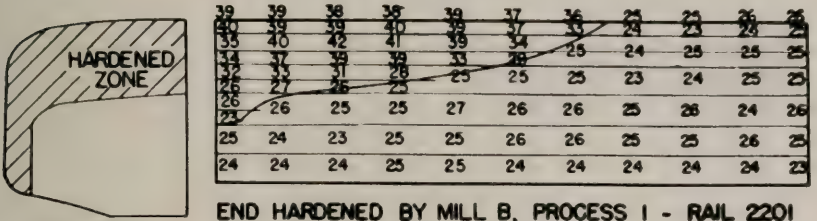
16. **Hardness and Metallographic Tests of Specimens Representing the C. & O. End-Hardened Test Rails.**—When the Chesapeake & Ohio end-hardened test rails were rolled at each of the four rail mills, two three-foot specimens from the same heat of steel were end hardened for laboratory tests. Also when the rails were rolled for the four field end-hardening processes two extra pieces were provided from each heat of steel to be end hardened for laboratory tests. Brief descriptions of the various end-hardening processes are given in Table 3, page 699.

Figs. 28 and 29 show Rockwell "C" hardness surveys of longitudinal sections with the hardened zones accurately drawn from etched specimens. Half of a transverse section ½ in. from the end of the rail is shown and the transverse shape of the hardened zone is indicated. The hardened areas are practically symmetrical on both sides of all rails which have been tested.

It will be noted that the hardened zones of specimens end hardened by Processes 10a and 10b are somewhat shorter than those found in rail ends hardened by other processes. It will be of interest to see whether this difference in length may cause differences in the amount of secondary batter (batter some inches distant from the end of the rail) developed under traffic.

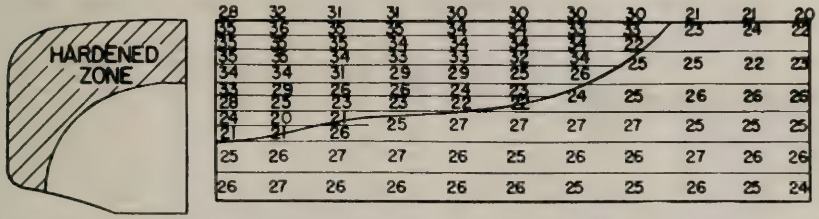
Most of the rail ends hardened in track by Process 10a, Hard, were later softened by a second treatment. After this softening laboratory specimens were found to have Brinell hardness only 17 numbers greater than rail ends hardened by Process 10b, Soft.

In preparing the laboratory specimens for the hardness surveys, about 0.025 to 0.030 in. of the top surface metal was removed from the rail heads. Especially on those rails which are decarburized rather deeply, this makes a considerable difference between the laboratory tests results and the field test results, in which only the mill scale was removed. In order to study decarburization, photomicrographs were taken of the rails



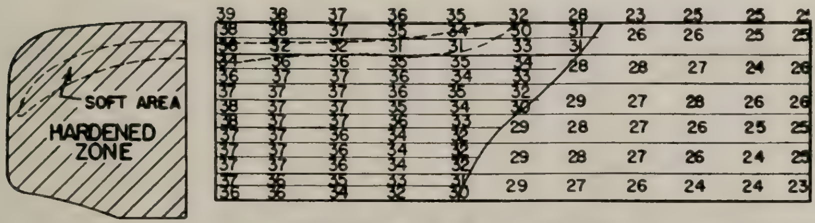
RAIL 2202

END HARDENED BY MILL B, PROCESS 1 - RAIL 2201



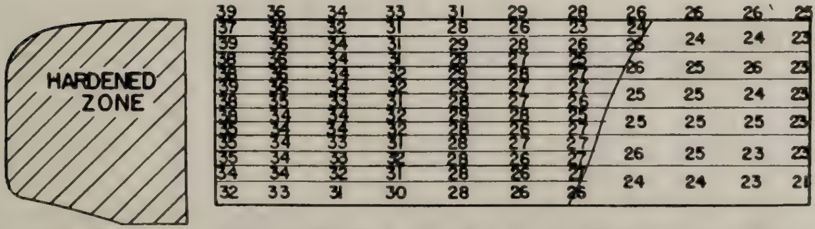
RAIL 2198

END HARDENED BY MILL E, PROCESS 2 - RAIL 2197



RAIL 2199

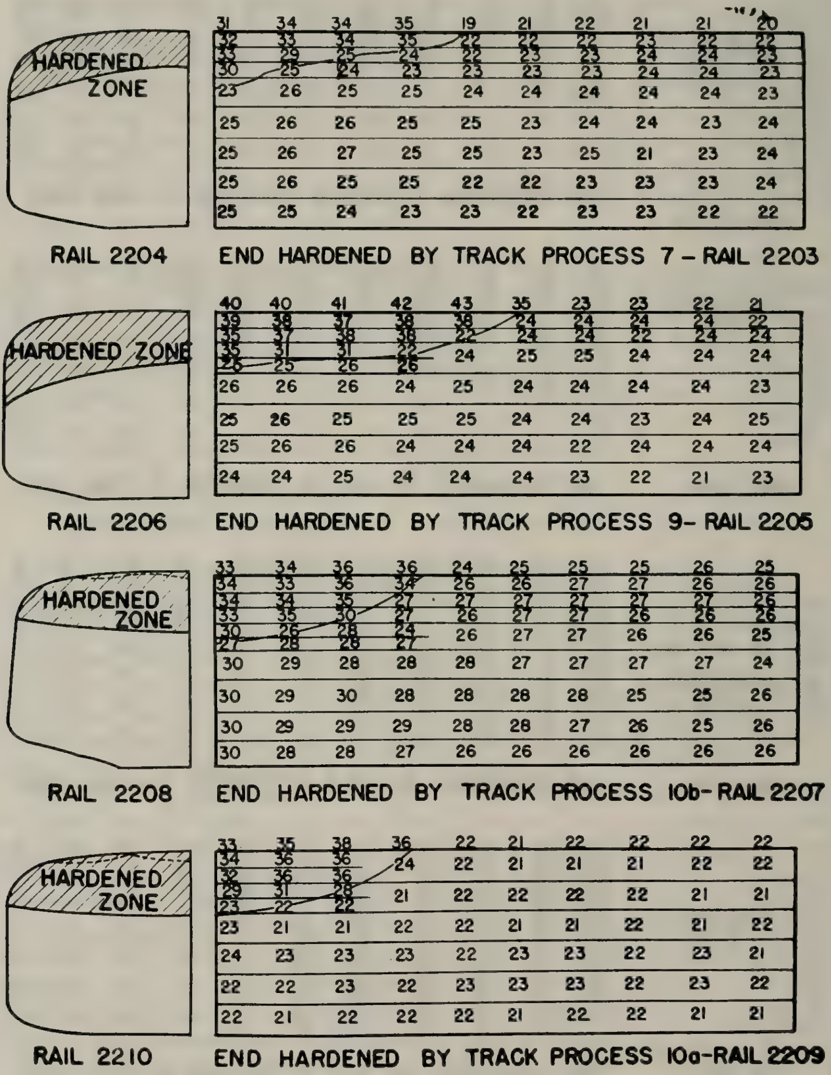
END HARDENED BY MILL I, PROCESS 3 - RAIL 2200



RAIL 2195

END HARDENED BY MILL D, PROCESS 6 - RAIL 2196

Fig. 28. Rockwell "C" Hardness Survey—Mill End-Hardening Processes.


HARDENED ZONE
RAIL 2204
END HARDENED BY TRACK PROCESS 7 – RAIL 2203
HARDENED ZONE
RAIL 2206
END HARDENED BY TRACK PROCESS 9– RAIL 2205
HARDENED ZONE
RAIL 2208
END HARDENED BY TRACK PROCESS 10b– RAIL 2207
HARDENED ZONE
RAIL 2210
END HARDENED BY TRACK PROCESS 10a–RAIL 2209

END HARDENED BY TRACK PROCESS 7 – RAIL 2203

31	34	34	35	19	21	22	21	21	20
32	33	34	35	22	22	22	23	22	22
33	29	25	24	22	23	23	24	24	23
30	25	24	23	23	23	23	24	24	23
23	26	25	25	24	24	24	24	24	23
25	26	26	25	25	23	24	24	23	24
25	26	27	25	25	23	25	21	23	24
25	26	25	25	22	22	23	23	23	24
25	25	24	23	23	22	23	23	22	22

END HARDENED BY TRACK PROCESS 9– RAIL 2205

40	40	41	42	43	35	23	23	22	21
39	38	37	38	38	24	24	24	24	22
35	37	38	38	22	24	24	22	24	24
35	31	31	22	24	25	25	24	24	24
25	25	26	26						
26	26	26	24	25	24	24	24	24	23
25	26	25	25	25	24	24	23	24	25
25	26	26	24	24	24	22	24	24	24
24	24	25	24	24	24	23	22	21	23

END HARDENED BY TRACK PROCESS 10b– RAIL 2207

33	34	36	36	24	25	25	25	26	25
34	33	36	34	26	26	27	27	26	26
34	34	35	27	27	27	27	27	27	26
33	35	30	27	26	27	27	26	26	26
30	26	28	24	26	27	27	26	26	25
27	28	28	27						
30	29	28	28	28	27	27	27	27	24
30	29	30	28	28	28	28	25	25	26
30	29	29	29	28	28	27	26	25	26
30	28	28	27	26	26	26	26	26	26

END HARDENED BY TRACK PROCESS 10a–RAIL 2209

33	35	38	36	22	21	22	22	22	22
34	36	36	24	22	21	21	21	22	22
32	36	36							
29	31	28	21	22	22	22	22	21	21
23	22	22							
23	21	21	22	22	21	21	22	21	22
24	23	23	23	22	23	23	22	23	21
22	22	23	22	23	23	23	22	23	22
22	21	22	22	22	21	22	22	21	21

Fig. 29. Rockwell "C" Hardness Survey—Field End-Hardening Processes.

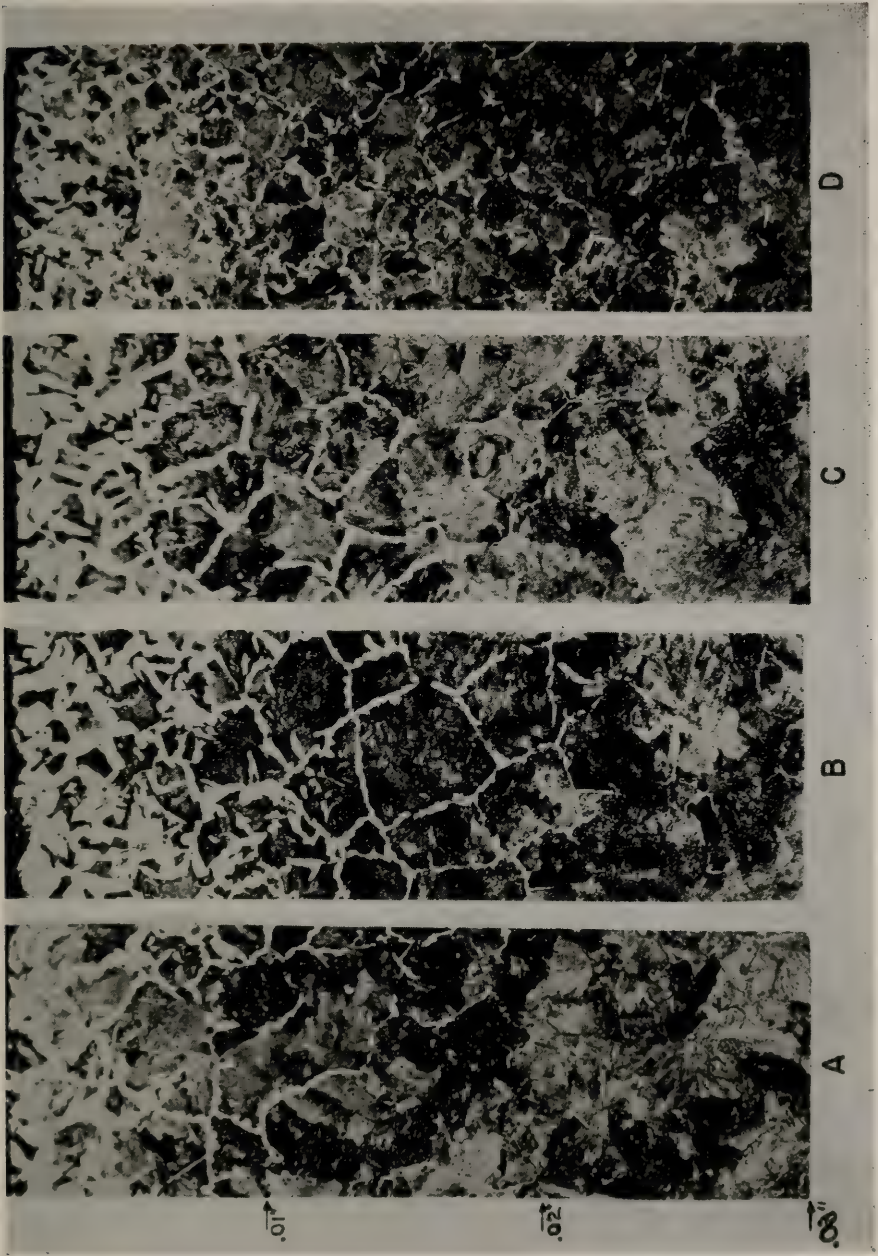


Fig. 30. Comparison of Decarburization of Surface of Rails from Four Mills Furnishing Rails for the Chesapeake & Ohio Service Tests.

Magnification 140 X. Etch two percent Picral.

A. Rail from Mill B, End-Hardening Process 1.—B. Rail from Mill E, End-Hardening Process 2 and Field-Hardening Processes 7, 9 and 10.—C. Rail from Mill I, End-Hardening Process 3.—D. Rail from Mill D, End-Hardening Process 6.

from different mills showing the decarburization on the top surface of the rails. Photomicrographs of the top surfaces of heads of rails from the four mills furnishing rails for the Chesapeake & Ohio tests are shown in Fig. 30.

The hardness tests of Rails 2199 and 2200 shown in Fig. 28 show a narrow zone about $\frac{3}{16}$ in. below the surface of the rail which is three to four Rockwell "C" numbers softer than the metal either above or below. This soft zone seems to be characteristic of the water spray quench from rolling heat, end-hardening Process No. 3, as it has been found in several rails end-hardened by this process besides the two furnished for this test. The exact cause of this soft zone is as yet not clearly understood. Fig. 31 shows a quenching crack on the end of test Rail 2199 at 6 X magnification. These quenching cracks have been found more often near the top corner of the rail, as in this case, but occasionally they have been found to extend nearly the entire width of the head parellel with and approximately $\frac{3}{16}$ in. below the top surface. They are always quite shallow and do not as a rule go into the end of the rail more than about $\frac{1}{32}$ to $\frac{1}{16}$ in. It will be of interest to determine from the Chesapeake & Ohio tests if any of these cracks progress under repeated wheel loads.

Laboratory examination of cross-sections of specimens hardened by Process 10b, Soft, shows very clearly the reason for the lower Brinell readings found for this

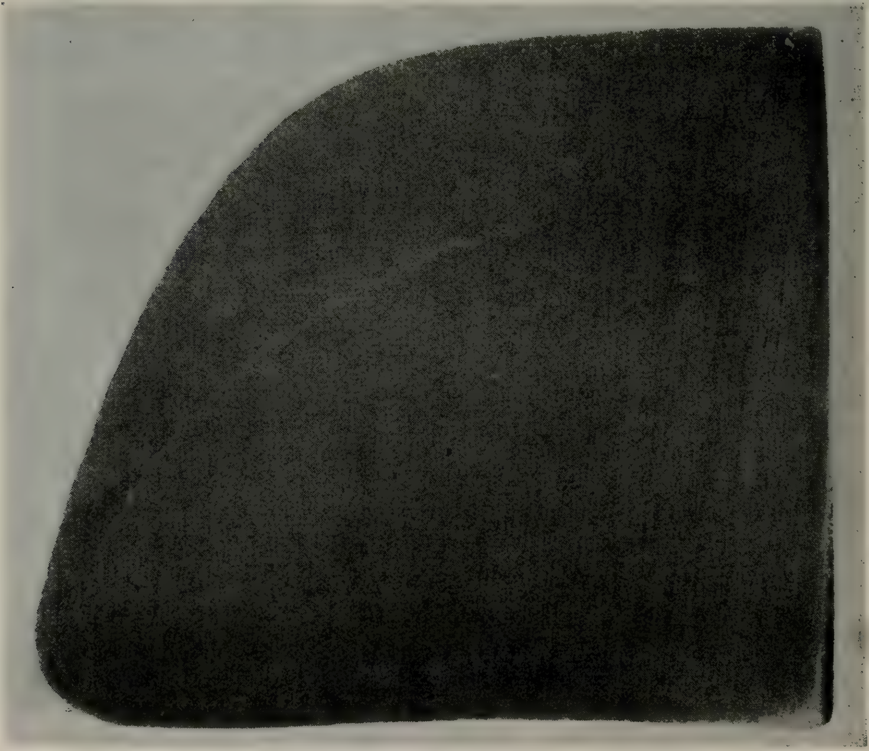


Fig. 31. Macrograph of Crack on End of Rail Head End-Hardened by Process 3.
Magnification 6 X. Polished with emery paper—not etched.
The tread of the rail is at the top of the macrograph. These cracks are only 1/32 to 1/16 inch deep.

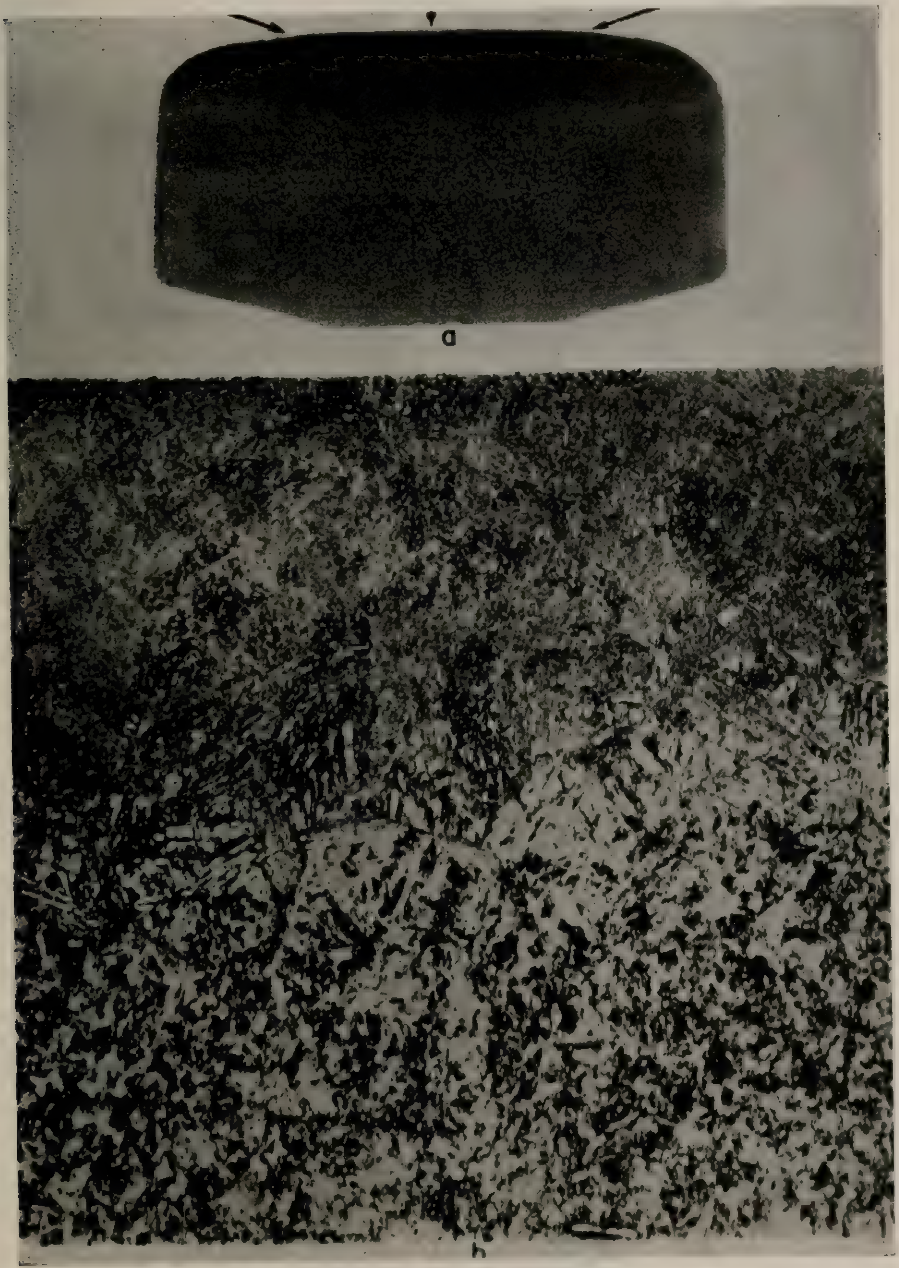


Fig. 32. Location of Scallops and Microstructure of Rail End-Hardened by Process 10b, Soft.

(a) Cross-section of rail end-hardened by Process 10b, Soft, one-half inch from rail end. Etched in Ammonium Persulphate. Note three narrow light colored scallops along the top edge of rail.

(b) Microstructure at junction of hard scallops and supporting metal. Magnification 200 X. Etched in three percent Picral.

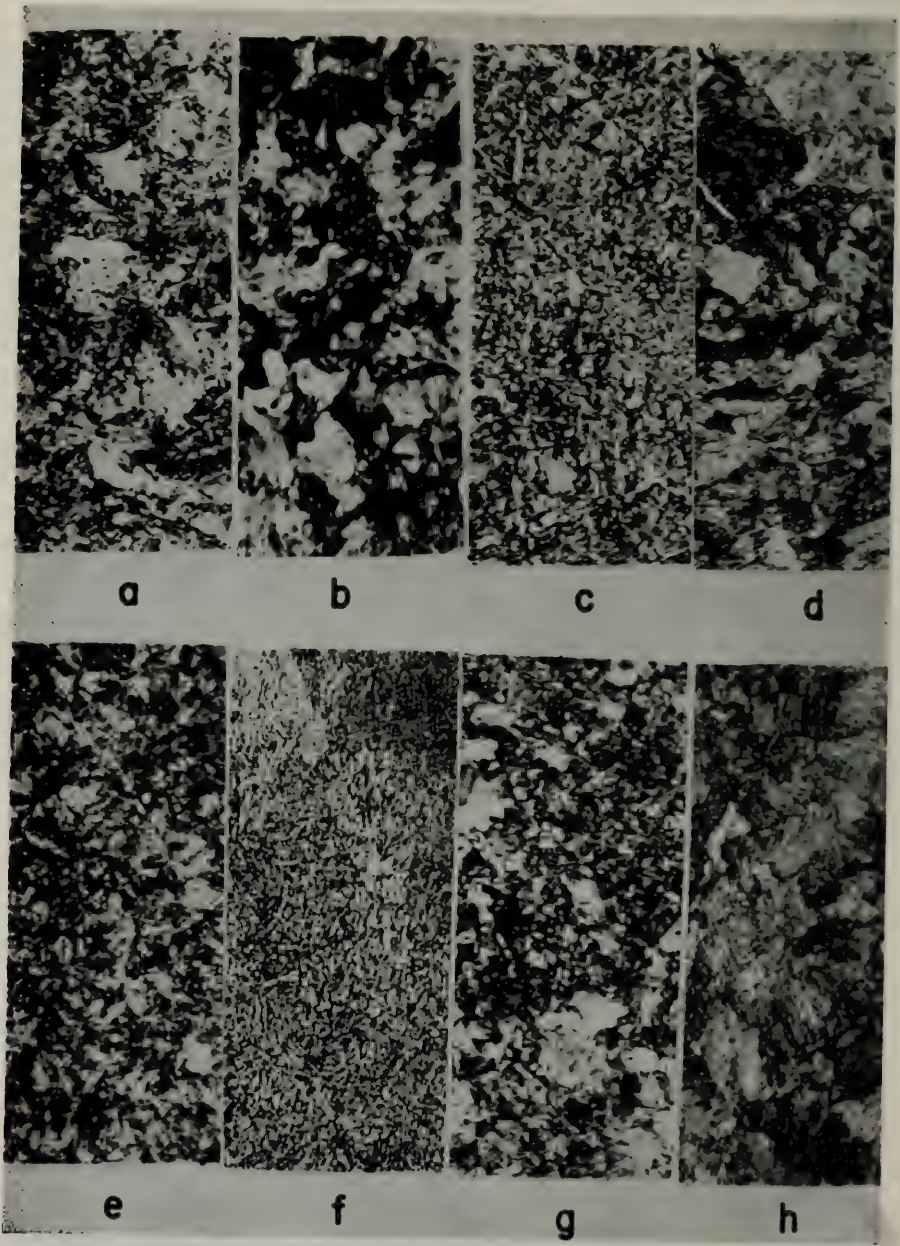


Fig. 33. Crystalline Structure of End-Hardened Samples from Chesapeake & Ohio Test Rails.

Magnification 380 X. Etch three percent Picral.

(a) Rail No. 2201, Mill End-Hardened by Process 1.

(b) Rail No. 2197, Mill End-Hardened by Process 2.

(c) Rail No. 2200, Mill End-Hardened by Process 3.

(d) Rail No. 2196, Mill End-Hardened by Process 6.

(e) Rail No. 2204, Field End-Hardened by Process 7.

(f) Rail No. 2206, Field End-Hardened by Process 9.

(g) Rail No. 2210, Field End-Hardened by Process 10a, Hard.

(h) Rail No. 2208, Field End-Hardened by Process 10b, Soft.

process during the second field tests in June. (See Table 4, page 707). Fig. 32 (a) shows a photograph of a transverse section of a rail hardened by Process 10b, Soft, etched in ammonium persulphate solution. At the tread of the rail will be seen three shallow scallops (indicated by arrows) symmetrically located across the width of the rail. Fig. 32 (b) is a photomicrograph at 200 X magnification, showing in the upper half the structure of the steel in the scallop and in the lower half the structure of the steel beneath the scallop.

The top metal was originally quenched fast enough to produce martensite which has been tempered by heat from the metal below. The rate of cooling of the metal in the lower half of the photomicrograph was only fast enough to produce sorbite which etches considerably darker with ammonium persulphate than the tempered martensite in the scallops. (See Fig. 32 (a)).

Careful Rockwell "C" hardness tests made on the top surface over the scallops were 4 to 7 Rockwell "C" numbers higher than readings taken between the scallops. The April, 1939, Brinell tests were taken directly over the center scallop and the June, 1939, tests were ¼ in. to the side of the first tests which placed them in the softer area. The locations of the three harder areas across the width of the rail correspond to the locations of the three rows of holes in the water quenching nozzle used to end harden Process 10 rails.

A similar examination was made of a specimen end hardened by Process 10a, Hard, and it was found that the thickness of the hard layer, as indicated in Fig. 29, Rail 2210, was greater on these rails so that the surface metal between the scallops was hardened to such a depth that the Brinell impressions did not penetrate into the softer metal underneath.

The photomicrographs shown in Fig. 33 show structures of end-hardened material as obtained from rail samples representing end-hardened test rails in the Chesapeake & Ohio track north of Carey, Ohio. The photomicrographs were taken on a transverse section ½ in. from the end of the rail and ⅛ in. from the tread. The structures shown are average representations of the hardened material at 380 X magnification. It will be noted that there is considerable variation in the size of grains produced by the different processes.

VI. Mechanical Tests of Specimens from Samples of Chesapeake & Ohio End-Hardened Test Rails

By S. W. Lyon

17. **Introductory.**—The mechanical test results herein reported were obtained from tests of unnotched Charpy impact and tension test specimens machined from rail samples representing test rails in the Chesapeake & Ohio track at Carey, Ohio. Table 3 lists and gives a brief description of the end-hardening processes which were applied to the mill end-hardened and field end-hardened series of rails in the test track and also to the representative rail samples from which the mechanical test specimens were obtained.

18. **Test Procedure.**—Fig. 34 (a) shows the method of cutting specimens from the various rail samples. Besides the specimens from the end-hardened material a companion series of unhardened specimens was machined from each rail sample to provide comparative data as to the effectiveness of the hardening processes. Fig. 34 (b) shows the type of Charpy specimen and Fig. 34 (c) the type of tension specimen used. The four mill end-hardening processes produced sufficient end-hardened material in the

rail ends so that the hardened specimens were entirely from the hardened material and gave quantitative results indicative of the properties of the end-hardened material.

On the other hand, the relatively shallow depth and short length of the end-hardened material produced in the ends of the rail samples treated by the field end-hardening processes precluded the possibility of obtaining test specimens having the critical sections entirely of the hardened material; Fig. 34 (b) illustrates this point. Therefore, with the amount of end-hardened material in the specimens obtained from the field end-hardened rails varying from specimen to specimen and also throughout the various processed rails no very satisfactory quantitative comparisons between hardened and unhardened metal can be obtained. It was felt, however, that the Charpy impact tests and the tension tests of specimens so machined as to include the maximum amount of end-hardened material available would, along with the companion untreated specimens from the same rails, give at least a qualitative if not quantitative com-

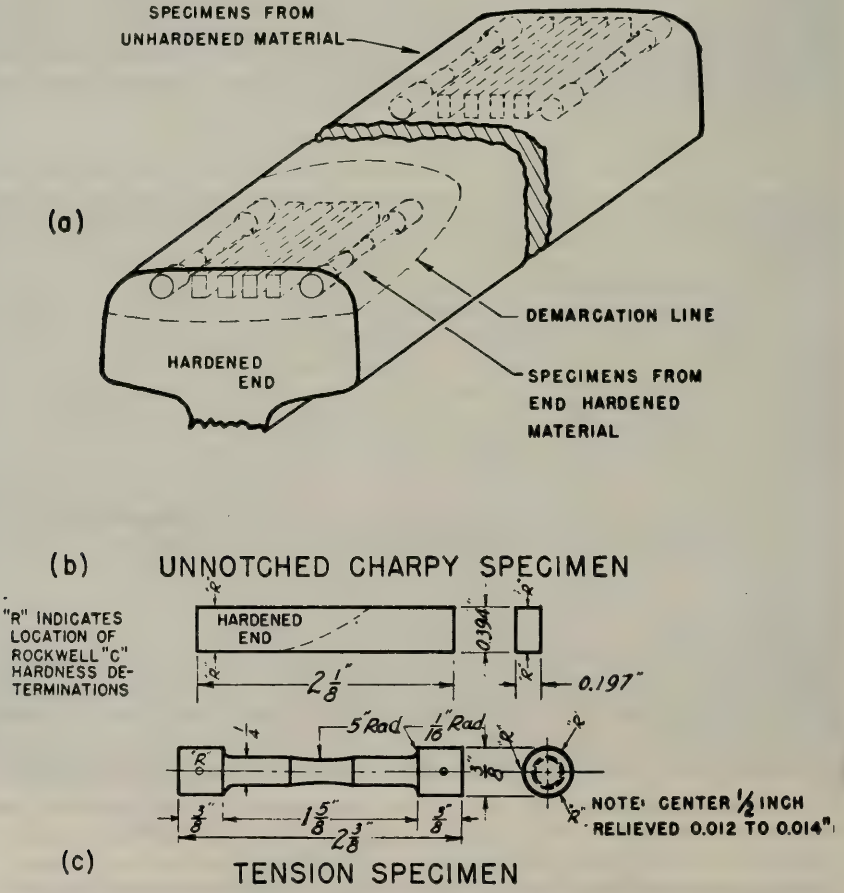

SPECIMENS FROM UNHARDENED MATERIAL
(a)
DEMARCATION LINE
HARDENED END
SPECIMENS FROM END HARDENED MATERIAL
(b)
UNNOTCHED CHARPY SPECIMEN
"R" INDICATES LOCATION OF ROCKWELL "C" HARDNESS DETERMINATIONS
HARDENED END
R
0.394
$2\frac{1}{8}$"
0.197"
5" Rad
$\frac{1}{16}$" Rad
"R"
$\frac{3}{8}$"
$1\frac{5}{8}$"
$\frac{5}{8}$"
$2\frac{3}{8}$"
$\frac{5}{16}$
NOTE: CENTER ½ INCH RELIEVED 0.012 TO 0.014"
(c)
TENSION SPECIMEN

Fig. 34. Scheme of Cutting Mechanical Test Specimens from Samples Representing Chesapeake & Ohio End-Hardened Test Rails.

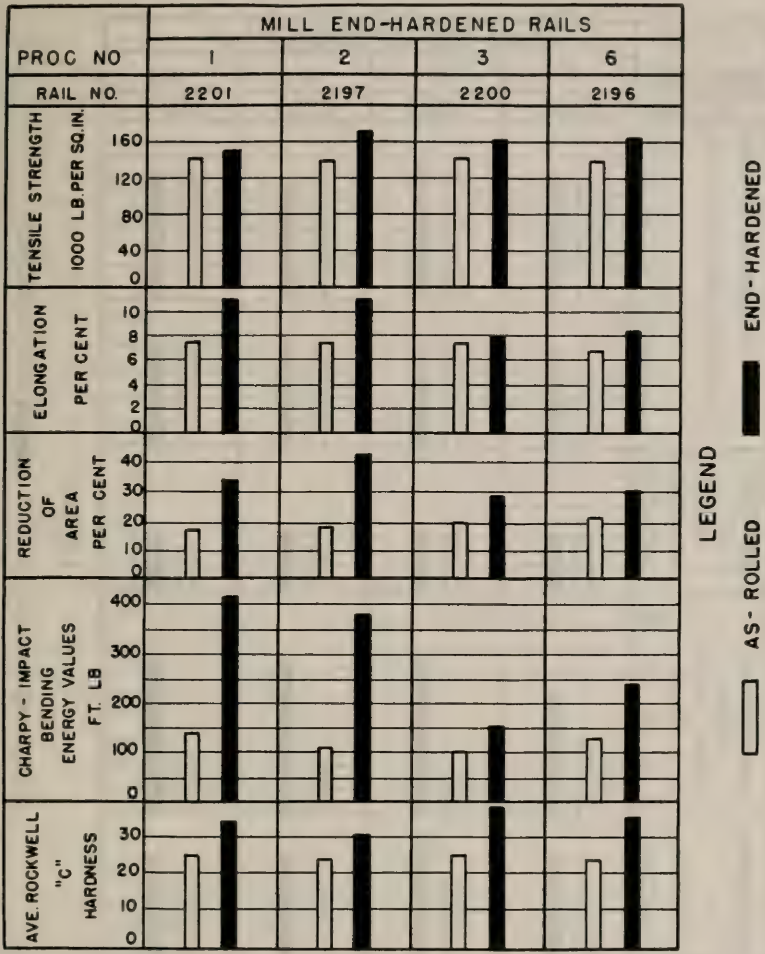


Fig. 35. Summary of Results of Mechanical Tests of Specimens Representing Chesapeake & Ohio Mill End-Hardened Rails.

parison between unhardened and hardened material and hence are an index of the effectiveness of the various field end-hardening practices.

For the specimens from the field end-hardened rail ends, Rockwell "C" hardness determinations were taken at the locations shown in Figs. 34 (b) and (c). Where the material was uniform throughout the specimens, as in those from the mill end-hardened samples and all companion specimens of unhardened rail steel, hardness determinations were taken at both ends instead of the hard end as show in Fig. 34 (b) and (c). The hardness determinations taken on any one specimen were averaged.

19. **Results of Tests.**—Fig. 35 gives a summary of the results of the mechanical tests carried out on the mill end-hardened rails. Examination of the summary reveals that, for the rails tested, all four mill end-hardening processes give increased values of

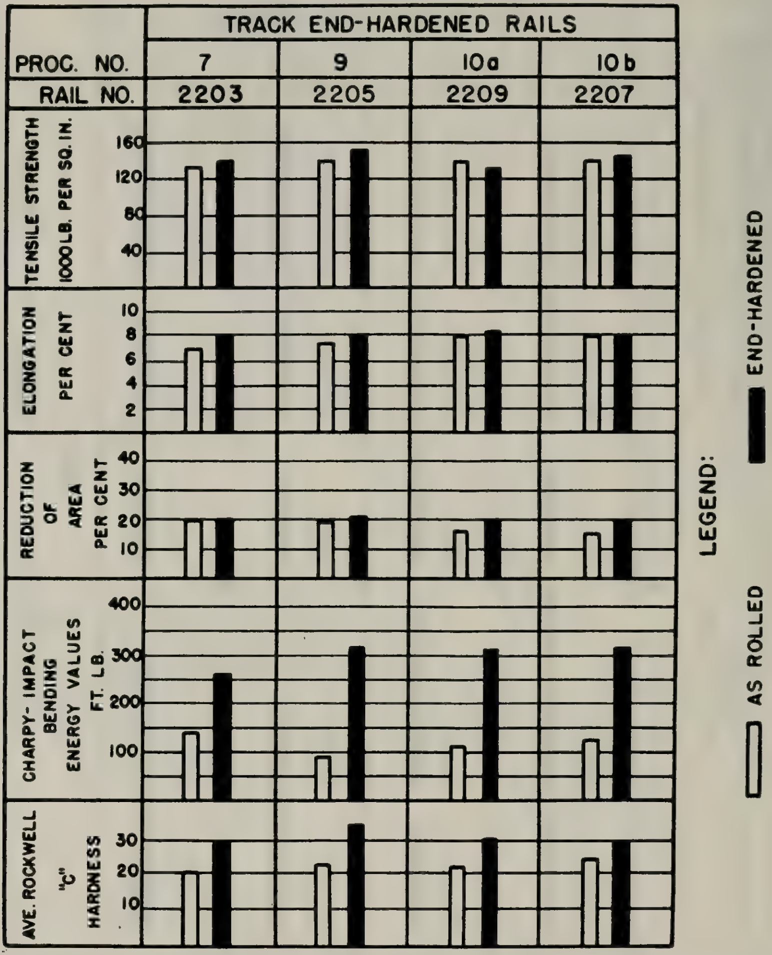


Fig. 36. Summary of Results of Mechanical Tests of Specimens Representing Chesapeake & Ohio Field (Track) End-Hardened Rails.

tensile strength, percent elongation, percent reduction of area and toughness for the end-hardened material as compared to the unhardened rail steel. For these rails which were tested the data indicate that in general the end-hardening Processes 1 and 2 increased the elongation, reduction of area and impact values somewhat more than did Processes 3 and 6.

The results of the mechanical tests carried out on the field end-hardened rails are summarized in Fig. 36. Except for the tensile values obtained for Rail 2209, Process 10a, for the rails tested all four field end-hardening processes give, in general, increased values of tensile strength, percent elongation, percent reduction of area, and toughness for the end-hardened material as compared to the unhardened rail steel. Rail 2209 end-hardened by Process 10a, Hard, which shows a lower value for tensile strength of the hardened material as compared to the as-rolled rail steel, was hardened originally with the intention of obtaining a hardness of approximately 450 Brinell. After the hardening was completed it was found that considerably higher values of hardness had been obtained, and, to reduce this high hardness, a second hardening treatment was applied to the rail ends originally hardened by this process. The second treatment reduced the hardness considerably and this is offered as a possible explanation of why the tensile strength of the hardened material is lower than the value obtained from the as-rolled steel of the same rail. It should be remembered, in considering all of these mechanical test results for the field-hardened rails that the test results as previously explained are at best roughly approximate quantitative results.

The micrographs shown in Fig. 33, (a) through (d), were obtained from the end-hardened material produced in the test rails by the mill end-hardening processes while those shown in Fig. 33, (c) through (h), were obtained from the end-hardened material in the field end-hardened rails. A comparison of the plotted results of mechanical tests shown in Figs. 35 and 36 with the corresponding microstructures is of interest. Apparently other factors than microstructure are involved in any explanation of ductility and toughness. It can be readily seen that what we usually consider as desirable microstructure (e.g. Fig. 33 (c)) did not insure the highest mechanical test values as given by the static tension and Charpy impact tests.

Figs. 35 and 36 also give the average hardnesses which, as previously explained, were determined by taking Rockwell "C" hardness readings at various locations on each unnotched Charpy and tension test specimen. It should be remembered that this method gives average hardness rather than maximum surface hardness and therefore the plotted values cannot be directly compared with those obtained in track and which are given in Table 4, and Figs. 28 and 29 of this report.

VII. Toughness and Other Mechanical Tests on Specimens from Rolled Rails

By S. W. Lyon

20. **Introductory.**—Rail failures due to spalling out of metal near rail ends are occasionally encountered in service. The cause of such failures has, in many cases, been charged to the embrittlement of the metal at the tread of the rail by cold working due to traffic. It is, also, the opinion of many that such failures occur more often during cold weather. If such failures were encountered previous to the comparatively recent widespread use of end-hardened rails, will heat-treated hardened steel at the rail ends affect the frequency of occurrence of spalling (i.e. especially of the hardened material) after these rails have been in service for some time?

As no information was available on the effect of rolling (cold working) on the toughness of unhardened or hardened rail steel at normal or subnormal temperatures, laboratory tests were undertaken to furnish such data. The rails previously rolled for batter measurement furnished the material from which to obtain test specimens. These end-hardened rails included both 112-lb. and 131-lb. sections and rails end hardened by four processes. Unnotched Charpy specimens were so machined and tested to give data on the toughness of unhardened and end-hardened rail steel in the rolled and unrolled condition and tested both at + 70 deg. and 0 deg. F. Table 5 gives an outline of the test program.

TABLE 5

OUTLINE OF TEST PROGRAM

Item	*Source of Test Specimens*	*Testing Temperatures*	
1	Rail Not Rolled—Not End Hardened	+70° F.	0° F.
2	Rail Rolled—Not End Hardened	+70° F.	0° F.
3	End-Hardened Rail—Not Rolled	+70° F.	0° F.*
4	End-Hardened Rail—Rolled	+70° F.	0° F.

* No material available to carry out tests at this temperature. Tests indicated above were made on rails end-hardened by each of the four different processes.

21. **Methods of Testing.**—Fig. 37 (a) shows the method of cutting the various series of specimens from the rolled and non-rolled rails. Care was taken in machining the specimens from the rolled rails so that the faces including the rolled material were but lightly finished ground, not more than 0.005 in. of rolled material being removed in any case. These specimens were tested with the rolled side in tension. The type of fractional-width Charpy specimen used for these tests is shown in Fig 37 (b).

Briefly stated, the testing procedure used for the testing at 0 deg. F. consisted in bringing the specimens to the desired temperature in a bath of acetone cooled in dry ice (solid CO_2), quickly placing them in the Charpy impact machine and testing before appreciable temperature fluctuation was possible.

22. **Results of Tests.**—Fig. 38 presents a summary of the results obtained. In order to permit a direct comparison of the various impact values, for a given end-hardening process the result obtained for the unhardened rail, not rolled, tested at + 70 deg. F., has been considered as the basic value and is ploted as 100 percent. Results of the other tests for that process have been computed as percentages of this basic value.

It should also be noted in Fig. 38 that under the item "End-Hardened Rail Not Rolled" (at + 70 deg. F.) the values are presented as greater than a given percentage. These values were obtained from the test values given in the "Summary of Results of Mechanical Tests of Mill End-Hardened Rails" presented on page 821, Fig. 5, AREA Proceedings, Vol. 39, 1938. The results in that graphical summary were obtained using full-width unnotched Charpy specimens which developed when tested, energy values in excess of 223 ft.-lb., the testing machine capacity. Therefore the plotted values in Fig. 38 for this item, while not definitely evaluating the percentage increase, indicate that the actual values are in excess of those shown.

Further examination of Fig. 38 will show that the rail not rolled, not end hardened, was the material most affected by lowering the testing temperature from + 70 deg. to 0 deg. F. On the other hand, the rolled end-hardened material was least affected by temperature change. In fact with the exception of Process 6, an increase in toughness was noted with a decrease in temperature of testing. Why this increase should be obtained is not readily explainable, but as soon as the rolling-load tests now in progress are completed additional rolled material will be available to permit checking these results.

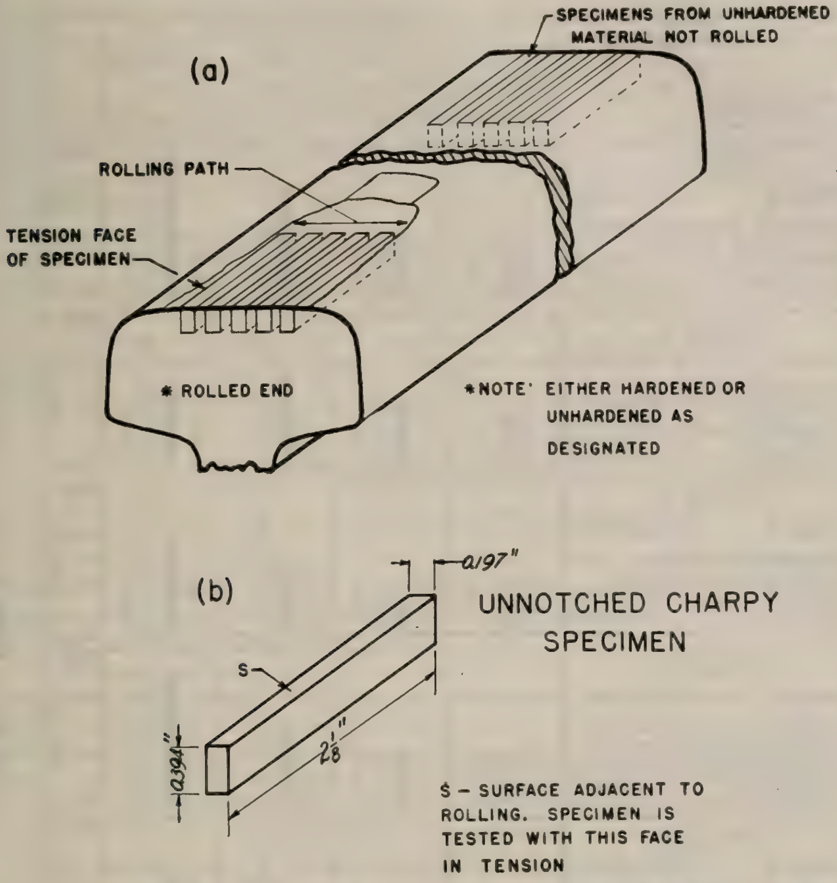
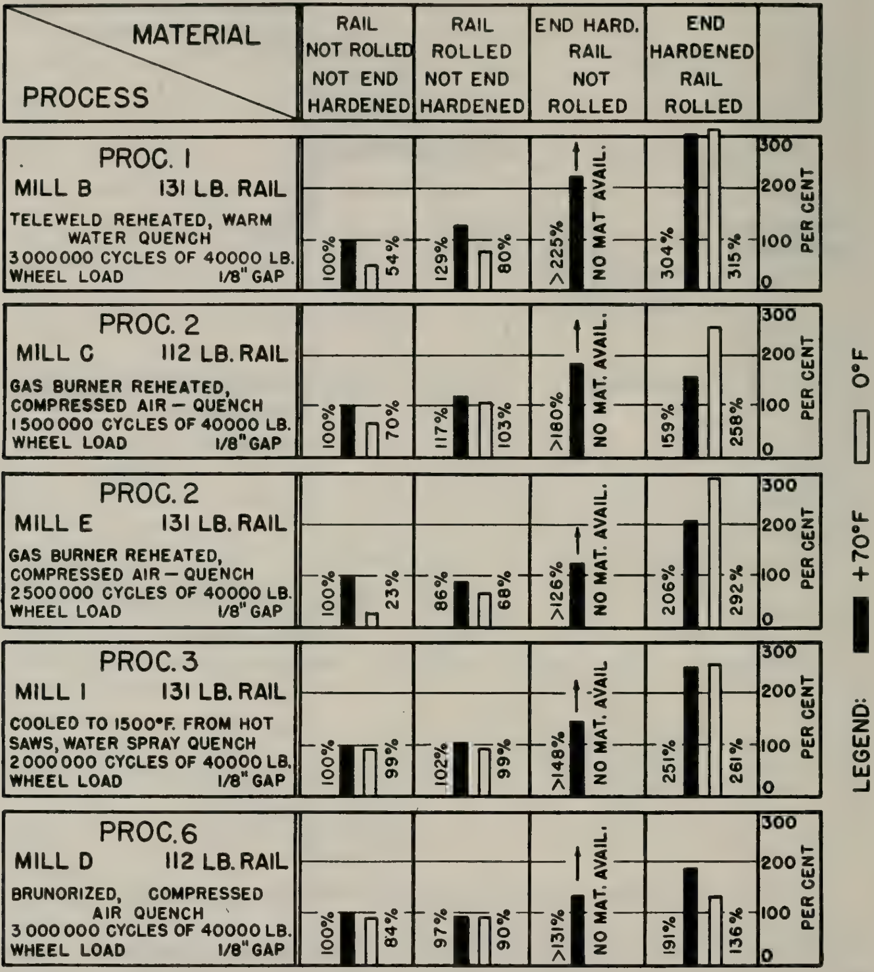

(a)
SPECIMENS FROM UNHARDENED MATERIAL NOT ROLLED
ROLLING PATH
TENSION FACE OF SPECIMEN
* ROLLED END
* NOTE: EITHER HARDENED OR UNHARDENED AS DESIGNATED
(b)
0.197"
UNNOTCHED CHARPY SPECIMEN
S
0.394"
$2\frac{1}{8}$"
S – SURFACE ADJACENT TO ROLLING. SPECIMEN IS TESTED WITH THIS FACE IN TENSION

Fig. 37. Scheme of Cutting Charpy Specimens from Rail Samples.

The significant point to be gained from these data is that the end-hardened material that has been rolled showed relatively high toughness after rolling when tested at either + 70 deg. or 0 deg. F. While no direct comparison can be drawn between the end-hardened material not rolled and the end-hardened material rolled, due to reasons previously considered, the residual toughness after rolling is still high and well above that developed by the unhardened rail. On the other hand, a slight loss of toughness was shown by the rolled, unhardened material for several processes. In conclusion it may be said that these test results indicate that the toughness of end-hardened rail steel is affected little, if any, by rolling (cold working) or by temperature in the range in which the testing was carried out.

23. **Work in Progress.**—These tentative results on the effect of cold rolling and end hardening on the toughness of rail steel, especially the effect at low temperatures seem sufficiently important to justify further tests on rails all rolled from the same ingot. Short lengths of 131-lb. rail for these tests have been rolled at Mill D and ends of different pieces have been hardened by Processes 1, 2, 3 and 6—the mill end-hardening



NOTE:

PLOTTED VALUES BASED ON PER CENT OF IMPACT VALUES OBTAINED FOR UNHARDENED RAIL NOT ROLLED.

ALL PLOTTED PERCENTAGES WERE CALCULATED FROM AVERAGE TEST RESULTS OBTAINED FROM THREE OR MORE SPECIMENS.

Fig. 38. Summary of Results of Charpy (Un-notched Bar) Tests of Specimens from Cold-Rolled Rails.

processes used on the rails in the test track on the Chesapeake & Ohio at Carey, Ohio. These short-length specimens are to be made up into test joints and each test joint is to be subjected to 2,000,000 cycles of a 40,000-lb. load in a rolling-load machine. Batter data will be taken for these joints, and afterward specimens cut from them will be subjected to toughness tests of at least two temperatures. Other mechanical tests may be made if it is found feasible.

24. **Work in Progress.—Fatigue Tests of Heat-Treated Rail Steel.**—In the Fifth Progress Report of this investigation test results have been given on the toughness (energy required to fracture) of rail steel given various heat treatments to produce a series of specimens with graded hardness values. The application of the various end-hardening processes to rails to produce increased resistance to batter at rail joints is a problem in heat treatment, and a study of the effect of heat treatment on the mechanical properties of rail steel may be expected to yield valuable results in connection with the end-hardening of rails.

The tests whose results have been reported include the usual tensile tests, and toughness tests (impact-bending and impact-tensile tests). Until recently no method was available for machining the harder specimens, and no fatigue tests were made, since fatigue specimens must be given their final shaping in the heat-treated condition. Recently a method of grinding hardened specimens to shape has been developed in the shop of the Talbot (materials testing) laboratory and a series of fatigue tests is in progress. The heat treatments give a range of hardness from Rockwell "C" 20 to "C" 65.

VIII. Non-Destructive Tests

By J. L. Bisesi, assisted by R. S. Jensen and G. B. Bliss

25. **The Echo Method.**—This proposed non-destructive method of determining the presence (or absence) of shatter cracks in new rails was suggested by Mr. F. M. Graham, assistant engineer of standards of the Pennsylvania Railroad and has been mentioned in the Fifth Progress Report.

The theory involved in this test is based on the well known phenomenon of echoes of sound waves. It is known that sound travels at different speeds through different materials and that when a sound wave passes from one material to another reflections are set up from the surfaces and echoes are created. A wave of stress travels through a steel rail at approximately 17,000 ft. per sec. and follows the law of the behavior of sound waves in an elastic medium. A shatter crack in a rail then might be expected to act as a different material, from which the wave would be reflected. An impact on the end of the rail will produce a wave of vibration or stress in it. In a clear rail it seemed reasonable to expect that the first cycle of the wave of stress should be a simple wave whereas in a shatter-cracked rail, where the wave may be reflected from shatter cracks, a complex wave form would be expected. That is, in the case of the shatter-cracked rail the complex wave of stress should be made up of a simple wave as given by the clear rail, plus superimposed waves reflected from shatter cracks.

The tests as made in the laboratory included a cycle of operation in which a solenoid-operated rod struck the rail to start the vibration which was picked up by a Piezo-electric crystal detector mounted on the end of the rail. The generated voltage in the crystal pickup was brought through a suitable resistance-coupled amplifier to a vibrating-string oscillograph. The oscillograph was equipped with three galvanometers, one to indicate the time of contact between the striking rod and the rail, the second to show the wave of vibration and third to give a record of the timing wave. The record was made on a strip of film which was mounted on the recording drum of the oscillograph. The shutter of the drum was so controlled by electro-magnetic relays that it opened just before the rod struck the rail and closed just as the drum completed one revolution. A few oscillograms have been taken on several rails, both clear and shatter cracked. Film speeds up to approximately 300 in. per sec. were used and each oscillogram recorded several cycles of vibration at the natural frequency of the longitudinal vibration of the rail. These oscillograms were taken both with the pickup device at the struck end of the rail and also at the other end of the rail. It was found that the shape of the curves on the oscillogram for a given rail could be reproduced.

An analysis of these oscillograms indicated that even in sound rails several harmonics and other frequencies were present in each oscillogram, superimposed on the natural frequency of the rail. A Fourier analysis of the wave disclosed that some of these frequencies were not harmonics of the longitudinal vibration of the rail but were caused by transverse vibrations. It was thought that the sharpness of the blow struck the rail by the solenoid plunger created a combination of longitudinal and transverse vibrations which gave rise to undesirable harmonics and thus distorted the oscillographic record. (When a long slender body such as a rail is balanced at the middle and set into vibration the tendency is for transverse vibrations to build up). Another factor involved is the fact that the frequencies of some of the harmonics found in the oscillograms are near the natural frequency of the oscillograph elements being used which further complicates the oscillograms.

The transverse vibration could possibly be eliminated by a different method of supporting the rail but no method of support has yet been found that will not also affect the longitudinal vibration. The interference caused by the natural period of the oscillograph elements could be eliminated by the use of cathode ray equipment which it would be necessary to build. This equipment would make use of a single tube having three cathode rays, each ray having its own set of deflecting plates and amplifiers. One of the rays would be used for a timing wave, the second for the wave of vibration of the rail, and the third to show the time the striking plunger is in actual contact with the end of the rail. Such equipment would also require a large photographic lens for purposes of recording.

So far as the present work is concerned no differentiation could be made between the oscillograms taken of the vibration of clear rails and those of shatter-cracked rails. In view of the fact that Dr. A. V. deForest at the Massachusetts Institute of Technology has found that in striking two bars together, a single large discontinuity in one of the bars did not affect the form of strain wave at any point in that bar, it is thought that it was not worth while going to the high expense necessary to build this equipment or to go any further with these tests.

26. **Measurements of Magnetic Fields.**—The shape and intensity of the magnetic field around a fissure or other defect is important in non-destructive field tests such as detector car tests. With this idea in mind attempts have been made from time to time to develop equipment for measuring the effect of a discontinuity in a rail on the shape of the magnetic field around the rail.

This equipment in its present form consists of a coil ⅜ in. in diameter which may be placed in the magnetic field near a rail which is carrying current. It is mounted on a long shaft and operated by a trigger and spring arrangement so that the coil, when released, turns through an angle of 180 deg. The ends of the coil winding are brought to a ballistic galvanometer. The device was calibrated by inserting the coil in a field of known strength and it was found that the deflection of the galvanometer was directly proportional to the flux cut by the coil. The direction of the field is obtained quite accurately by taking the resultant of two vector readings (vertical and horizontal). The device is mounted on a base so that the coil can be moved in three directions: across the head of the rail, along the head lengthwise, and up and down.

Preliminary tests have been made on a 10-ft. section of 105-lb. rail containing a 40 percent fissure as determined by the drop-of-potential test. In making these tests a current of 2,000 amp. was passed through the rail and readings taken of the field strength and direction of field. These readings were taken across the rail just above the fissure and at a point seven inches away from the fissure. It had been determined before these tests were made that the effect of the fissure on the magnetic field around the rail did not extend more than two inches away from the fissure so that the point seven inches away represented the normal rail.

Some preliminary results of these tests are shown in Figs. 39 and 40. Fig. 39 A represents the lines of equal field strength at various heights above the rail. The broken lines represent the field strengths above the normal part of the rail while the full lines represent the field strengths above the fissured portion of the rail. These curves indicate that the field above the fissure is weaker than that over the normal part of the rail. This is further indicated in Table 6 in which the given values of field strength in gauss are taken above the center of the rail when 2,000 amp. are passed through the rail.

Fig. 39 B gives a more striking illustration of the variation between the field strength above the fissure and above a normal section of the rail. The values from which this figure was drawn were taken at a constant level of ¼ in. above the rail with 2,000 amp. flowing through it. In this figure the broken line again represents the value of the field strength over the normal portion of the rail while the full line represents the values obtained over the fissure. In this curve the value of maximum field strength (100 percent) represents a magnetic field of 62 gauss. The peculiar shape of the curve at the left corner of the rail is due to the natural distortion of the field caused by the sharp corner produced by the wear on the rail.

TABLE 6

VALUES OF FIELD STRENGTH ABOVE CENTER OF RAIL

Height Above Rail, Inches	*Field Strength Gauss*		*Difference in Percentage of Normal Values*
	Normal Section	*Fissured Section*	
¼	62.0	56.7	8.5
½	56.6	53.2	6.0
¾	51.6	48.6	5.8
1	47.0	44.0	4.5

Fig. 40 shows the direction of the field around the rail at the points at which magnetic measurements were taken with the rail carrying 2,000 amp. The arrows drawn from the points of measurement indicate that the lines of force encircle the rail in the same manner as they would in an ordinary conductor carrying current. The readings for the gage side of the rail are not shown since they are approximately the same as those shown on the outside of the rail. The data taken in order to obtain this figure indicate that the difference between the direction of the field near the fissured section and that near a normal section of the rail was very slight (about three degrees). In order to keep the picture clear, therefore, the comparison is not shown.

27. **Detector Car Operation.**—This year, as in the past, the operation of detector cars over the AREA test rails in service has been followed. A change has been made in the method of conducting these tests from that followed during the past few years in that the cars were allowed to proceed under commercial testing conditions instead of checking each indication. This was done in order to save time and expense of testing

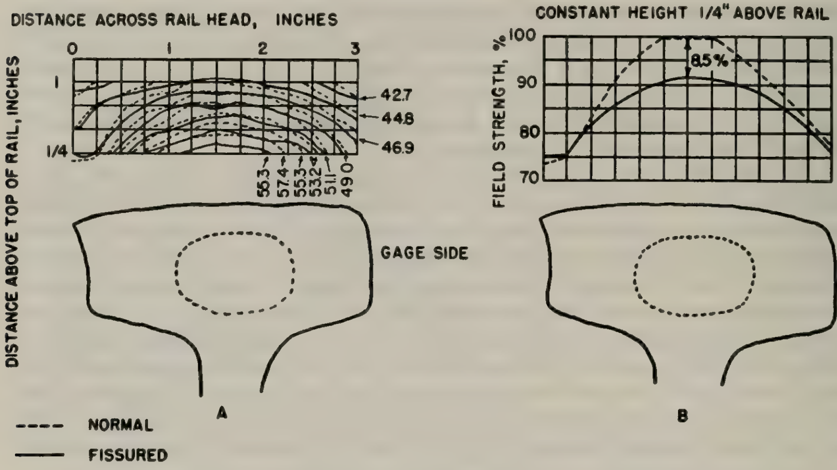


Fig. 39. Magnetic Field Strength Distribution Over Fissured and Normal Sections of a Rail Carrying Current.

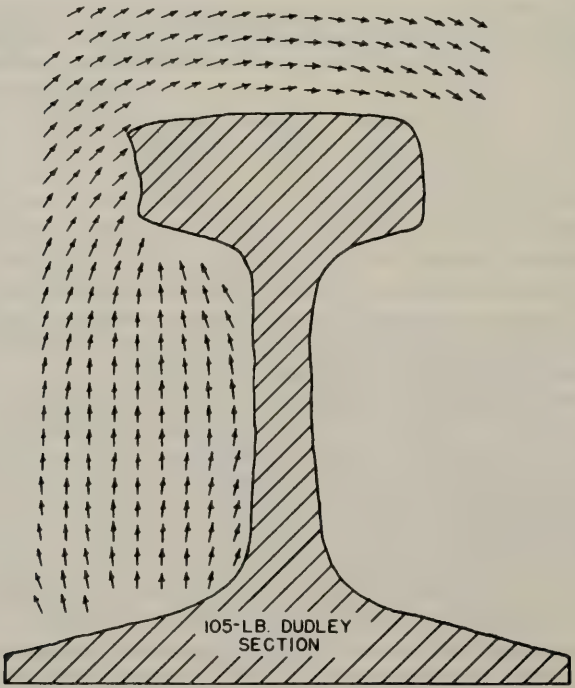


Fig. 40. Direction of Magnetic Field Around a Rail Carrying Current.

more thoroughly. The rails mentioned in these tests were rolled in 1931 and 1932, hot-bed cooled and put in service on the Baltimore & Ohio and the Santa Fe beginning in 1932.

A. **Baltimore & Ohio Railroad.**—The annual inspection of the test rails in service in various locations on the Baltimore & Ohio Railroad was made in September, October and November by means of the Sperry single-crew method of testing and as explained above, under commercial testing conditions. In all, 11 failed rails were located, 10 of which were marked for removal. These rails are listed in Table 7, page 730. The eleventh rail, not removed, was found on the Toledo division. It was the same rail, Heat 27525, Ingot 1, Rail D, Mill E, which was located on a previous test and marked "to be watched by the section crew." It contained a horizontal split head which had not grown very much in size after the additional year's service.

Of the rails removed, one of this same heat and ingot (Rail F) gave indication of containing a 15 percent transverse fissure. This, although it is the third failure, is the first transverse fissure found in rails from this heat. Five other transverse fissures were found, one in each of the following Heats 50110, 74190, 71182, 55052 and 51109, the latter three being the first defects located in those heats, whereas 50110 is the badly shattered heat in which there have been many failures including the two vertical split heads found this year. In addition to these failures two progressive fractures, originating at spots burned by slipping locomotive drivers, were found in Heat 16980, Mill E. These are the first failures in this heat as well as the first evidence of this type of failure in any of the test rails in service.

Seven of these rails have been delivered to the laboratory of the Rails Investigation. They are the two progressive fractures in Heat 16980 and the fissures in Heats 51109, 27525, 74190, 71182 and 55052. The laboratory examination of these rails has not been completed at the present writing but the results will be reported later.

Service Failures:—Toledo Division.—During the past year two service failures have occurred in the test rail located in the Toledo division of the Baltimore & Ohio Railroad. The first occurred in Rail D, Ingot 3, of Heat 43118 on February 22, 1939, about 2½ months after the rail had been tested by means of the Sperry detector car. The failure was due to a transverse fissure just 20 in. from the end of the rail and just outside the end of the joint bar. The rail had carried 112,600,000 tons of traffic.

The second failure occurred on August 8, 1939, in Rail C, Ingot 1 of the same heat (43118) and the rail was broken 17 in. from the end. According to the failed rail report, Form 923, the size of the fissure was approximately 30 percent.

In both of these cases an investigation of the Sperry record tapes failed to reveal any indication of defect. This, however, might be due to the fact that the defect was so close to the joint that the detecting equipment was inoperative when it passed over the location of the fissure.

Pittsburgh Division.—No defective rails were located on the Pittsburgh division during the tests by the Sperry detector car, but two service failures have occurred in the test rail on this division, three months after the date of test. Both rails which failed were from Heat 74191, rolled by Mill A in 1931 and were laid in track in November, 1933. They had carried approximately 79,300,000 tons of traffic before failure. The failure of Rail B, Ingot 16, was caused by a transverse fissure of about 30 percent occurring about 50 in. from the receiving end of the rail. It did not cause any signal failure or train delay.

Rail E, Ingot 15 contained a horizontal split head. The rail did not break, however, and caused no train delay.

TABLE 7

DEFECTIVE TEST RAILS FOUND IN THE BALTIMORE & OHIO TEST SECTIONS. DETECTOR CAR TESTS, 1939

Heat No.	Ingot	Rail	Mill	Marked Defect	Traffic, Million Tons	Location M.P.+Pole
			TOLEDO DIVISION			
27525*	1	D	E	H. S. H.	57.4	76+12½
	1	F	E	15% I. T. F.	70.4	76+10
50110	5	D	D	V. S. H.	125.1	67+31½
	4	B	D	V. S. H.	125.1	67+32
	5	E	D	5% I. T. F.	125.1	67+24½
55052	1	C	D	20% I. T. F.	125.1	66+32
51109	1	B	D	5% I. T. F.	125.1	66+ 7
16980	8	A	E	P. F.	125.1	62+36
	19	A	E	P. F.	125.1	62+35
			CUMBERLAND DIVISION, Magnolia Cut-off			
74190	20	B	A	10% I. T. F.	79.5	8+25
71182	5	A	A	10% I. T. F.	79.5	9+14

* Also located in 1938 but not removed.

Note: I.T.F. = Internal transverse fissure.
H.S.H. = Horizontal split head.
V.S.H. = Vertical split head.
P.F. = Progressive fracture.

A study of the Sperry detector tape record shows indications of defect at the points of failure and also at other points on the rails. In justice to the operator of the Sperry car, however, it should be stated that these rails were located near the end of a curve in which the rails are badly flowed and it is exceedingly difficult to get a satisfactory test on flowed rail at any commercial speed of testing.

The failed rail is being sent to the laboratory and a report of the findings will be made in a later report.

Cumulative Record of Failures.—A cumulative record of the test-rail failures which have been found on the Baltimore & Ohio is shown in Table 8. In connection with this table it should be noted that traffic was discontinued on the Patterson Creek cut-off in May, 1932, after it had carried 1,500,000 tons of traffic and was resumed in October, 1939. No tests have been made on this track during that time. One additional rail not appearing on the table was removed from the section between Kesslers Bridge and Okonoko because it was excessively burned. This rail was the C Rail, of Ingot 6, Heat 209137 and was rolled by Mill B.

No failures have been found on the following sections of test rail.

Toledo division—Tippecanoe City to Troy, 804 rails which have carried approximately 90 million tons of traffic.

TABLE 8

CUMULATIVE RECORD OF FAILURES ON BALTIMORE & OHIO RAILROAD TEST RAILS

Division	*Location*	*Track*	*No. of Rails*	*Date Laid*	*Mill*	*Heat No.*	*Type of Failures*				*Million Tons*	*Total Failures*	*Etch* Tests*
							I.T.F.	*H.S.H*	*V.S.H.*	*P.F.*			
Toledo..	Dayton to Vandalia M.P. 62.5 to 68.1	Single	1529	2–32	D	50110	0	0	1	0	58.9	1	Heat 50110
						50110	1	0	0	0	73.0	1 Service	44 L; 30 T
						43118	1	0	0	0	73.0	1 Failures	Heat 43118 7 L; 4 T
						50110	3	0	0	0	89.2	3	
						43118	3	0	0	0	89.2	3	
						50110	6	0	0	0	109.7	6	
						43118	0	0	1	0	109.7	1	
						43118	1	0	0	0	112.6	1 Service	
						43118	1	0	0	0	118.0(est.)	1 Failures	
						50110	1	0	2	0	125.1	3	
						55052	1	0	0	0	125.1	1	2 L
						51109	1	0	0	0	125.1	1	Clear
					E	16980	0	0	0	2	125.1	2	Clear
	M.P. 76.0–76.4		53	10–35	E	27525	0	2	0	0	57.4	2	8 L
						27525	1	0	0	0	70.4	1	
	M.P. 76.4–78.1		657	3–36	D	47248	1	0	0	0	50.4	1	2 L
Pittsburgh	Layton to St. James	No. 2	1108	12–33	A	74191	1	1	0	0	79.3	2 Service Failures	1 L
Cumberland	Bardane to Kearneysville	No. 2	371	7–33	A	74098	1	1	0	0	92.5	2	7 L
						75102	0	1	0	0	92.5	1	2 L
	Kesslers Bridge to Okonoko	No. 3	1625	8–33	A	74191	0	0	1	0	68.3	1	1 L
						74190	2	0	0	0	68.3	2	3 L
						74190	1	0	0	0	79.5	1	
						71182	1	0	0	0	79.5	1	9 L; 2 T

* Number of longitudinal (L) and transverse (T) cracks found in one six-inch slice from samples shipped to the laboratory at the time of rolling.

Note: I.T.F. = Internal transverse fissure.
H.S.H. = Horizontal split head.
V.S.H. = Vertical split head.
P.F. = Progressive fracture.

Cumberland division—Hansrote, 51 rails on track No. 3 which have carried 80,000,000 tons of traffic. Patterson Creek cut-off, 142 rails which have carried 1,500,000 tons of traffic.

B. **Atchison, Topeka and Santa Fe Railway.**—The test rails laid in the Middle division of the Atchison, Topeka & Santa Fe Railway were last tested on February 20, 1940. This is single track territory carrying freight on the cut-off between Eldorado and Ellinor, Kan. The traffic up to January 1, 1940, was 103,317,000 tons.

These rails have been tested at least once each year by means of the company-owned detector car, but no defects have been found on any of these tests. Table 9, however, shows a cumulative record of the rails removed from service for various reasons.

TABLE 9

CUMULATIVE RECORD OF TEST RAILS REMOVED FROM SERVICE, ATCHISON, TOPEKA & SANTA FE RAILWAY

Mill	*Heat*	*Number of Rails*	*Cause of Removal*
C	Various	5	Curve worn
	Various	2	Kinked
	Various	2	Stock rail
D	Various	15	Curve worn
	Various	2	Stock rail
E	18583	2	Crushed head
	24439	1	Crushed head
	25518	1	Crushed head
	Various	4	Curve worn
	Various	1	Stock rail

IX. Rolling-Load Tests of Joints for Batter

By N. J. ALLEMAN and H. F. MOORE

28. **General Outline of Rolling-Load Tests.**—The rolling-load tests for batter which have been continued steadily during the past year were made on three of the rolling-load machines. Fig. 12 of the Third Progress Report (1937) presents a diagram of the rolling-load machine and Fig. 13 of that report shows the micrometer used for measuring batter of rail-joint specimens. Fig. 13 of the Fifth Progress Report gives a summary of the rolling-load batter tests with rail joints of ⅛-in. joint gap.

29. **Results of Recent Rolling-Load Tests.**—The principal rolling-load tests carried on this year were tests of joints with ¼-in. gaps and other joints with zero gaps. Fig. 41 shows the results of these tests in a tabulation similar to that shown in Fig. 13 of the Fifth Progress Report.

A comparison of the rolling-load batter tests is also shown in this figure. The joints with hardened ends were made using mill end-hardening Processes 1, 2, 3 and 6. These joints were similar to those in test rails at Carey, Ohio. (See Chapter IV).

It may first be noted that Fig. 41 shows general results somewhat similar to those shown in Fig. 14 of the Fifth Progress Report. In general, rails with hardened ends showing less than Rockwell "C" 35 do not show much gain over the unhardened rail ends.

When the effect of joint gap is considered, however, another factor enters the situation with the joints with zero gap. Three of the twelve joints with zero gap chipped at the ends. Two of these were made with unhardened rails while the third one was made by mill end-hardening Process 3. All these chipped joints showed relatively high batter as compared with the other joints of their class, (hardened or unhardened). In the tests of joints with ¼-in. gap and ⅛-in. gap no chipping occurred. It may here be noted that the ends of the rails with zero-gap joints were chamfered 1/16 in. deep and 3/32 in. back. The top surface of the rail was ground flat to a width of 1½ in.

Considering now the batter of the rail joints which did not chip, the average batter is as follows:

Description of Rail Joints	*Batter (inches)*		
	Zero Gap	*⅛-in. Gap*	*¼-in. Gap*
Unhardened rail ends	0.0095	0.0179	0.0204
Hardened rail ends	0.0047	0.0055	0.0083

For the joints which did not chip the batter increases with the width of the gap. In the rolling-load tests the speed of wheel is relatively slow, perhaps 1½ m. p. h. Under the speeds found in railroad service the effect of width of gap might be different. It is hoped that light can be thrown on this point by the results of the Carey field tests.

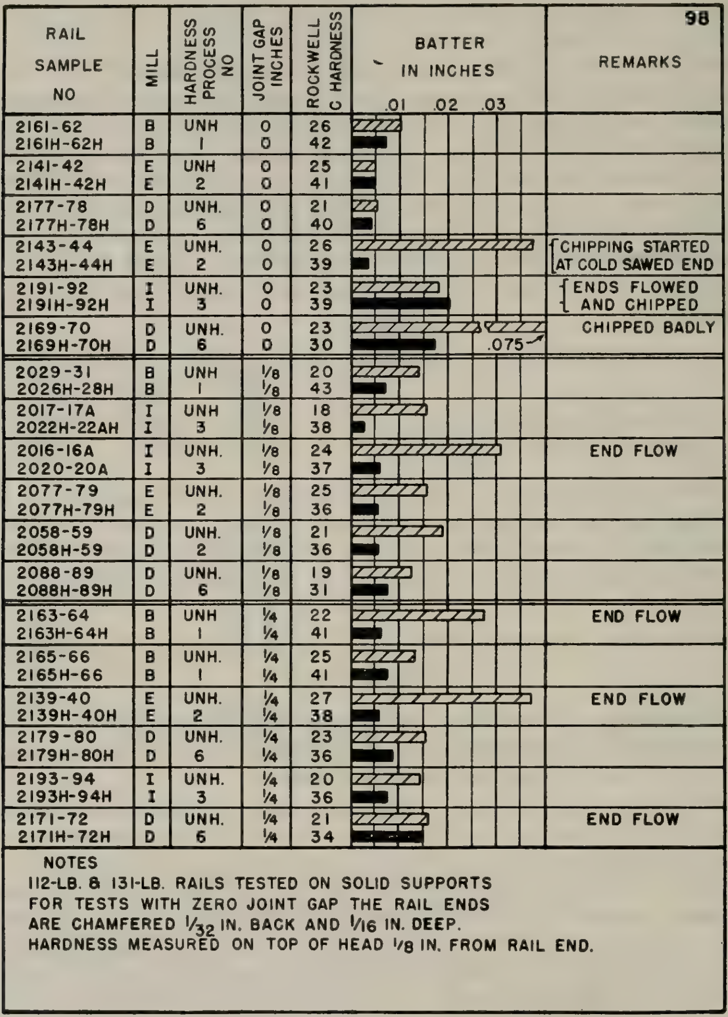
X. Bend Tests and Drop Tests for Accepting or Rejecting Rails

By H. F. Moore

30. **Advantage of Bend Tests as Compared With Drop Tests.**—This matter has been discussed in considerable detail in the Fifth Progress Report. The advantages of the two tests may be briefly summarized as follows:

Both tests give some measure of the energy required to fracture a certain piece of steel rail. The drop test made on the standard M.C.B. drop test machine does not do this very accurately because the anvil of the machine is mounted on springs and those springs absorb a considerable amount of the energy of the falling weight. The percentage of the energy absorbed by the springs compared with that absorbed by the rail varies, probably with different machines and certainly with rails of different elastic strength. A drop test made at the University of Illinois has actually "passed" a quite brittle rail which had a high elastic strength. The bend test gives not only the energy to break the specimen but also the load to break the specimen. It also gives an autographic record of the tests. The drop test can measure the energy for fracture only by the number of blows required for fracture. This measure is very unsatisfactory. Both drop tests and bend tests can be made quickly. The first cost of the bend test machine would be somewhat greater than that of a drop testing machine. The greatest advantage of the bend test over the drop test is the obtaining of a definite value of the resistance of the rail specimen to fracture,—a definite value measured either in energy or in force.

31. **Correlation of Drop Test Results and Bend Test Results.**—If a standard bend test is to be adopted it will be necessary to specify values either of force or energy required for fracture of a standard specimen. There has become available to the test party a large amount of data on drop tests and bend tests compiled by the laboratory force of the Pennsylvania Railroad during the study of bend tests made



RAIL SAMPLE NO	MILL	HARDNESS PROCESS NO	JOINT GAP INCHES	ROCKWELL C HARDNESS	BATTER IN INCHES	REMARKS
2161-62	B	UNH	0	26		
2161H-62H	B	1	0	42		
2141-42	E	UNH	0	25		
2141H-42H	E	2	0	41		
2177-78	D	UNH.	0	21		
2177H-78H	D	6	0	40		
2143-44	E	UNH.	0	26		CHIPPING STARTED
2143H-44H	E	2	0	39		AT COLD SAWED END
2191-92	I	UNH.	0	23		ENDS FLOWED
2191H-92H	I	3	0	39		AND CHIPPED
2169-70	D	UNH.	0	23		CHIPPED BADLY
2169H-70H	D	6	0	30	.075	
2029-31	B	UNH	1/8	20		
2026H-28H	B	1	1/8	43		
2017-17A	I	UNH	1/8	18		
2022H-22AH	I	3	1/8	38		
2016-16A	I	UNH.	1/8	24		END FLOW
2020-20A	I	3	1/8	37		
2077-79	E	UNH.	1/8	25		
2077H-79H	E	2	1/8	36		
2058-59	D	UNH.	1/8	21		
2058H-59	D	2	1/8	36		
2088-89	D	UNH.	1/8	19		
2088H-89H	D	6	1/8	31		
2163-64	B	UNH	1/4	22		END FLOW
2163H-64H	B	1	1/4	41		
2165-66	B	UNH.	1/4	25		
2165H-66	B	1	1/4	41		
2139-40	E	UNH.	1/4	27		END FLOW
2139H-40H	E	2	1/4	38		
2179-80	D	UNH.	1/4	23		
2179H-80H	D	6	1/4	36		
2193-94	I	UNH.	1/4	20		
2193H-94H	I	3	1/4	36		
2171-72	D	UNH.	1/4	21		END FLOW
2171H-72H	D	6	1/4	34		

NOTES
112-LB. & 131-LB. RAILS TESTED ON SOLID SUPPORTS
FOR TESTS WITH ZERO JOINT GAP THE RAIL ENDS
ARE CHAMFERED 1/32 IN. BACK AND 1/16 IN. DEEP.
HARDNESS MEASURED ON TOP OF HEAD 1/8 IN. FROM RAIL END.

Fig. 41. Batter After One Million Cycles of a 40,000-lb. Wheel Load.

something over twenty years ago. These records have been studied with very considerable care and the difficulty of getting correlated values for the two tests is very great. For one thing, the drop tests recorded were made practically all on head-up rails while the bend tests were made on the head-down rails. The nearest approach to correlation of results which has been obtainable is found in the test results from rails rolled at Mill A, and these results are shown in Fig. 42. Results from other mills showed so few breaks on the first blow that they did not seem to furnish a satisfactory basis for correlation. In Fig. 42 it will be noted that no rails failed on the first blow in the drop test when the corresponding bend test results showed more than 110,000 ft.-lb. of energy required for fracture. Very few broke when the energy required for

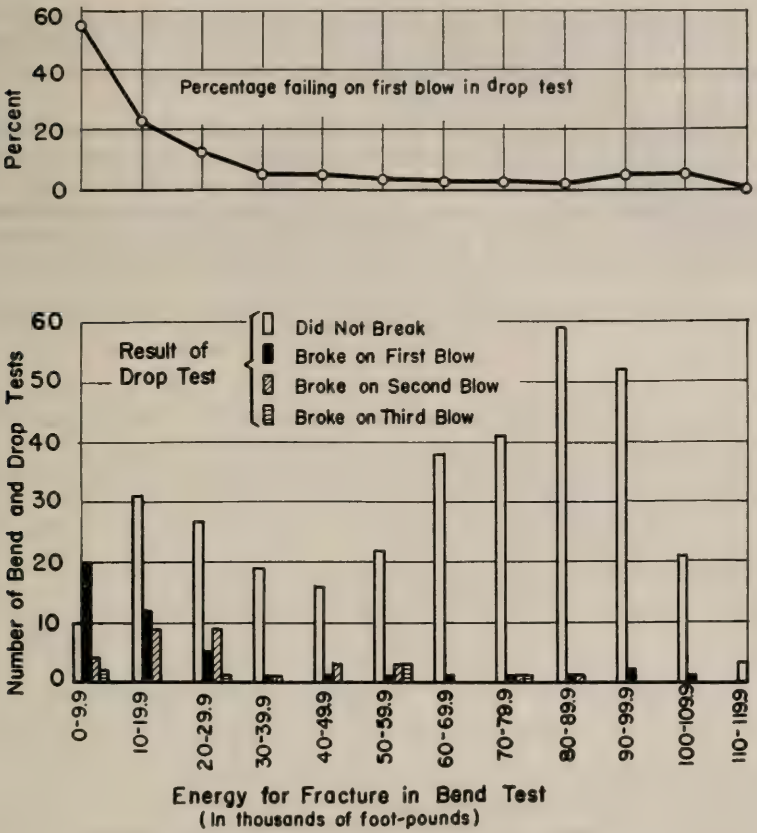


Fig. 42. Results of Bend and Drop Tests of 130-lb. P.R.R. Rails.
The results of the drop tests are indicated for each group of bend tests having the range of values of energy for fracture indicated.

fracture was greater than 30,000 ft.-lb. although six failures were recorded on rails which developed energy for fracture in the bend test ranging between 80,000 and 100,000 ft.-lb. From various bend tests made on rails at the University of Illinois, making allowance for the different span of specimens in the Pennsylvania Railroad tests, 100,000 ft.-lb. would be a fair dividing line between acceptable and non-acceptable rails of 131 lb. per yard on the basis of bend test results. Another viewpoint would give distinctly lower values. Taking the 131-lb. rail the drop test demands an energy of falling weight of 44,000 ft.-lb. The rail does not absorb all this energy. The springs under the anvil take a considerable portion. It might seem then that to require 44,000 ft.-lb. energy in the bend test would be fully as severe as the present drop test requirements. The preceding paragraphs have been written not as suggestions for definite requirements at the present time but as methods of approach to the problem. It seems very difficult to get any correlation between drop test and bend test results.

Any comparative series of tests, drop and bend, whether made at the rail mills or at some central laboratory would take a very long time because of the infrequent failure of rails under a single blow in the drop test and the uncertain significance of breaks under second, third, or fourth blows.

The following method of evaluation of bend test results is suggested. Make bend tests on a large number of rail specimens from different mills. The results of these tests may be expected to give an idea of the range of values which are obtained in current mill practice. These results may serve as a basis for establishing energy, load, and ductility requirements in acceptance tests. The data obtained in bend tests by Wickhorst, by the Pennsylvania Railroad and at the University of Illinois may also be of value.

Second Progress Report—Joint Investigation of Continuous Welded Rail

By H. F. Moore
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Howard R. Thomas
Special Research Professor of Engineering Materials, University of Illinois, Engineer of Tests, Joint Investigation of Continuous Welded Rail

and

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I. Introduction

1. **Organization of Investigation.**—This investigation, begun in September 1937, is carried on under the joint auspices of the Association of American Railroads and the Engineering Experiment Station, University of Illinois. The Association of American Railroads, through the Committee on Rail of the American Railway Engineering Association, appointed the following advisory committee for the investigation:

J. C. Patterson, Chief Engineer Maintenance of Way, Erie Railroad (Chairman)
P. O. Ferris, Chief Engineer, Delaware & Hudson Railroad
G. M. Magee, Research Engineer, Engineering Division, Association of American Railroads
C. E. Morgan, Superintendent Work Equipment and Track Welding, Chicago, Milwaukee, St. Paul & Pacific Railroad
G. R. Smiley, Chief Engineer, Lousville & Nashville Railroad

At the University of Illinois the work was placed under the general direction of Professor H. F. Moore. Close contact is maintained with Professor A. N. Talbot and the Special Committee on Stresses in Railroad Track. One-quarter of the time of Professor H. R. Thomas, engineer of tests, and of Professor R. E. Cramer, metallurgist, is given to this investigation. The assistance of Messrs. S. W. Lyon, J. L. Bisesi, E. C. Bast, and N. J. Alleman is gratefully acknowledged. Acknowledgment is also made of the cooperation of the following representatives of welding companies in preparing specimens and offering constructive criticisms of test methods and the form of presentation of the results:

Lem Adams, Vice-President, Oxweld Railroad Service Company
C. A. Daley, Maintenance of Way Engineer, Air Reduction Sales Company
J. H. Deppeler, Chief Engineer, Metal & Thermit Corporation
H. C. Drake, Director of Research, Sperry Products, Inc.

2. **Previous Work of the Investigation.**—In the First Progress Report* of this investigation there were published data and preliminary results of (1) metallographic studies of welded joints in rails, (2) mechanical tests of specimens cut from rail metal, weld metal and metal in the junction zone between weld and rail, (3) tests of full-section welded-joint specimens under repeated wheel load and (4) drop tests and bend tests of full-section specimens of welded joints. The "rolling-load" testing machine for

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* Proceedings of the American Railway Engineering Association, Vol. 40, pages 687–713 (1939).

subjecting rail-joint specimens to repeated wheel load was described, as was the testing rig for making bend tests of full-section rail joints. A bibliography on welded rails was printed as an appendix to the report. Attention was directed to the fact that all results obtained were preliminary and tentative.

3. **General Outline of the Work Since March 1939.**—In a general way the work reported in the First Progress Report has been continued. This is especially true in the case of rolling-load tests. Sixteen such tests have been completed, during which time 21,772,200 cycles of wheel load have been applied to specimens. This is equivalent to running the rolling-load machine continuously day and night for 252 days. A number of rolling-load tests of specimens with joint bars instead of welded joints have been tested. Further bend tests have been made and more micrographic study has been done. Plans have been made for the systematic reporting of welded rail failures in service.

4. **Types of Welded Joints Studied.**—Five different processes of welding rail have been studied. From all of these but one (Process D) joints with both 112-lb. rail and 131-lb. rail were furnished. Joints welded by Process D were furnished only with 131-lb. rails.

The detail of welding processes is covered rather fully in the First Progress Report. In general, the processes may be summed up as follows:

Process A. Rail joint welded by oxacetylene blow torch. A fusion weld made without pressure.

Process B. Similar to Process A but joints welded by a different company.

Process C. The Thermit process, using the intense heat generated by the transformation of aluminum to aluminum oxide. This process involves fusion, but after solidification of the molten metal has begun, pressure is applied.

Process D. An electric flash butt weld made with pressure. The weld is heated by striking an arc between the two rails to be joined and forcing the rails together at welding heat by pressure.

Process E. A gas butt weld with pressure. A special welding machine using oxacetylene gas is used and the rails are pressed together while welding.

In practically all the processes there is some heating for stress relieving or normalizing after the weld has been made and, of course, the grinding off of the excess metal over the tread and sides of the rail head.

II. Tests of Welded Joints Under Repeated Wheel Load

By N. J. Alleman and H. F. Moore

5. **Rolling-Load Testing Machine.**—The machine used for repeated-load tests of welded joints is called the "Rolling-load" machine. A halftone cut of the machine was shown in Fig. 8 of the First Progress Report. A diagrammatic sketch of the machine is shown in Fig. 1 of this second report for the benefit of those who may not have any other description available. The welded joint specimen S is pulled backward and forward under a wheel W, the load on which can be varied from zero to 75,000 lb. The load is applied through the lever L by means of a screw jack J, and is measured by the compression of the spring P. The maximum bending moment on the weld is equal to the load on the wheel times the distance from the center line of the weld to the point of contact of the wheel when the specimen is in its extreme left-hand position. A revolu-

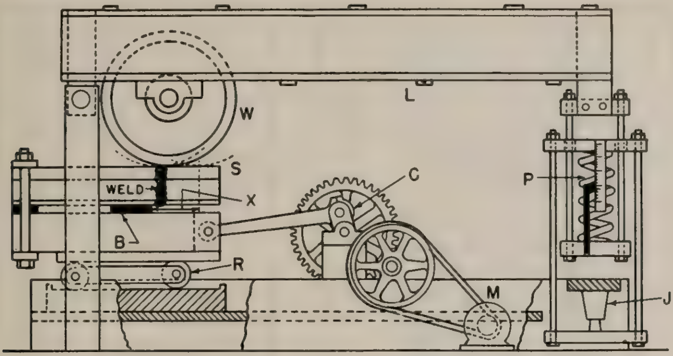

Fig. 1. Machine for Rolling Load Tests.

tion counter is attached to the crankshaft of the machine, and an automatic cut-off switch is operated by the drop of the lever *L* when a specimen breaks. The stroke of the machine is 12 in. and its speed is 60 strokes per minute.

6. **Procedure of Rolling-Load Tests.**—A number of specimens of each type of welded joint (not less than three) were tested for each of two weights of rail, 112-lb. and 131-lb.† The first specimen of each group was tested under a load of 75,000 lb. If the specimen broke before it had withstood 2,000,000 cycles of load a second specimen was put in under a lower load. If this specimen broke a third specimen was put in at a still smaller load and was tested to fracture, or until it had withstood 2,000,000 cycles of load. The selection of 2,000,000 cycles as the limiting number of cycles of stress is discussed in detail in the First Progress Report.

7. **Endurance Limit for Welded-Joint Specimens.**—The endurance limit for a given type of welded joint and given weight of rail is determined by drawing a stress-cycle (or S–N) diagram with wheel loads or bending moments as ordinates to an ordinary scale, and with number of cycles of stress for fracture as abscissas to a logarithmic scale. A line is drawn to fit the plotted points for specimens which break, and it is extended, if necessary, to intersect the vertical line for 2,000,000 cycles of load. The wheel load or bending moment represented by this intersection is taken as the endurance limit for 2,000,000 cycles of stress.

Figures 2 and 3 give S–N diagrams for the welds tested, and also S–N diagrams for rails without weld and rails with joint-bar joints. Whenever a specimen was removed from the machine without breaking, the plotted point for that specimen is marked with an arrow. Evidently an S–N diagram should not lie *below* such a plotted point. It is necessary in determining endurance limit for some of these S–N diagrams to estimate the endurance limit from rather unsatisfactory data. A few illustrations may be of service.

In the S–N diagram (Fig. 3) for gas fusion welds of 131-lb. rails the longest life of specimen was about 550,000 cycles. Three plotted points for the diagram fall closely on a straight line, and this line is extrapolated to 2,000,000 cycles. It is quite possible that the S–N diagram might flatten out like that in Fig. 2 for the gas pressure weld

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† No specimens of the electric pressure butt-welded joints using 112-lb. rails have been supplied to the test party.

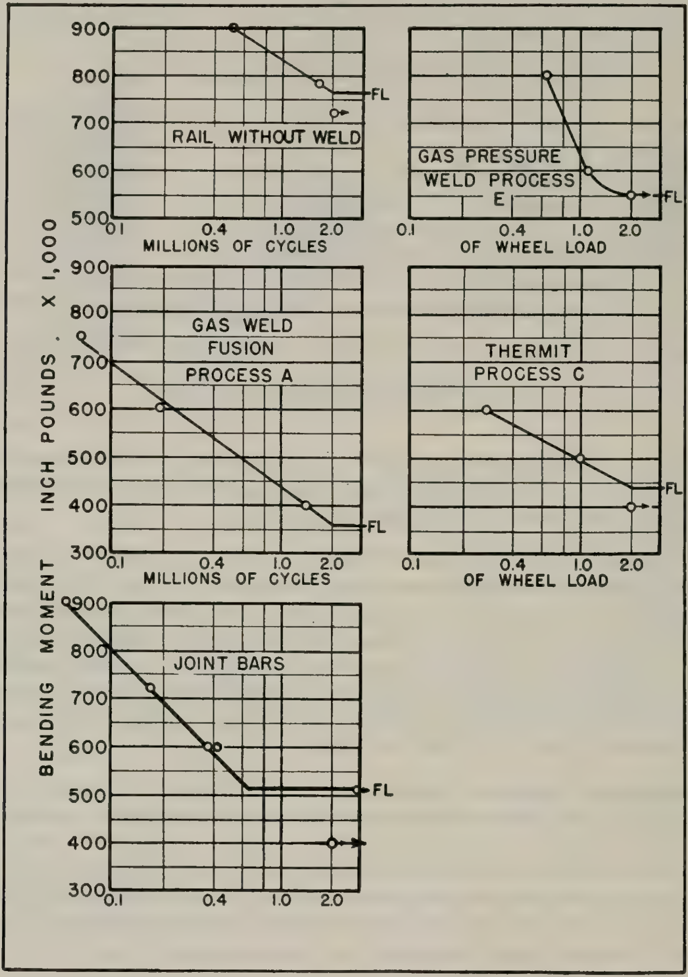

Fig. 2. Bending Moment-Cycle Diagrams for 112-lb. Rails, Joint Bars and Welded Rails. FL Denotes the Fatigue (Endurance) Limit.

specimens with 112-lb. rail. Then in Fig. 2 consider the S–N diagram for specimens with joint bars and 112-lb. rails. Evidently the S–N diagram should not pass below the plotted point for the specimen which did not fail after 3,028,600 cycles at 510,000 in.-lb., yet if the straight line connecting the three points for specimens which failed were extrapolated to 2,000,000 cycles, it would pass below the point for the unbroken specimen. The endurance limit is evidently less than 600,000 in.-lb. and not less than 510,000. It is estimated at 510,000.

8. **Types of Fracture of Welded Joints in Rolling-Load Tests.**—Figure 4 shows the three types of fractures which were found in welded joints, namely (a) failure by transverse fissure in head starting from some imperfection usually a minute

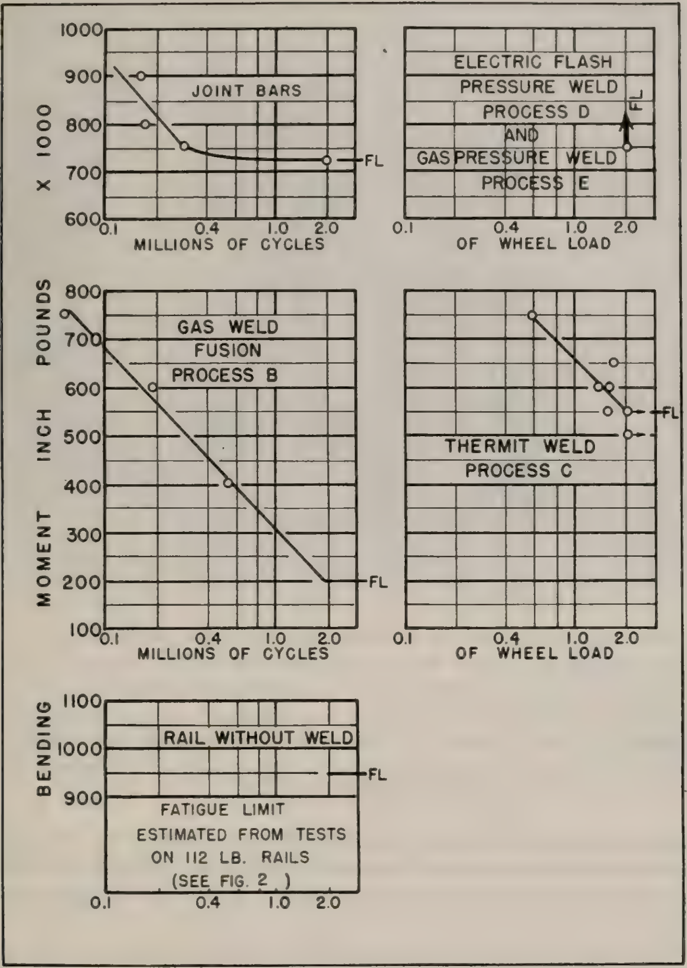

Fig. 3. Bending Moment-Cycle Diagrams for 131-lb. Rails, Joint Bars and Welded Rails. FL Denotes the Fatigue (Endurance) Limit.

crack, (b) failure starting in the web or at the junction of web and head—usually starting in some irregularity in welding surface which serves as a stress raiser, and (c) a fatigue failure by spreading crack starting near the corner of the tread of the rail—a conventional fatigue failure of the rail. Figure 4 (d) shows a typical rolling-load failure of a joint bar.

9. **Rolling-Load Tests of Joints Connected by Joint Bars.**—To secure a basis of comparison of the resistance of welded rail joints to repeated stress with that of joint-bar joints, a series of rolling-load tests on rails connected by joint bars is in progress. In this test the joint bars are carefully fitted and are tightened with a bolt tension of 20,000 to 25,000 lb. which is maintained as the rolling-load test proceeds.

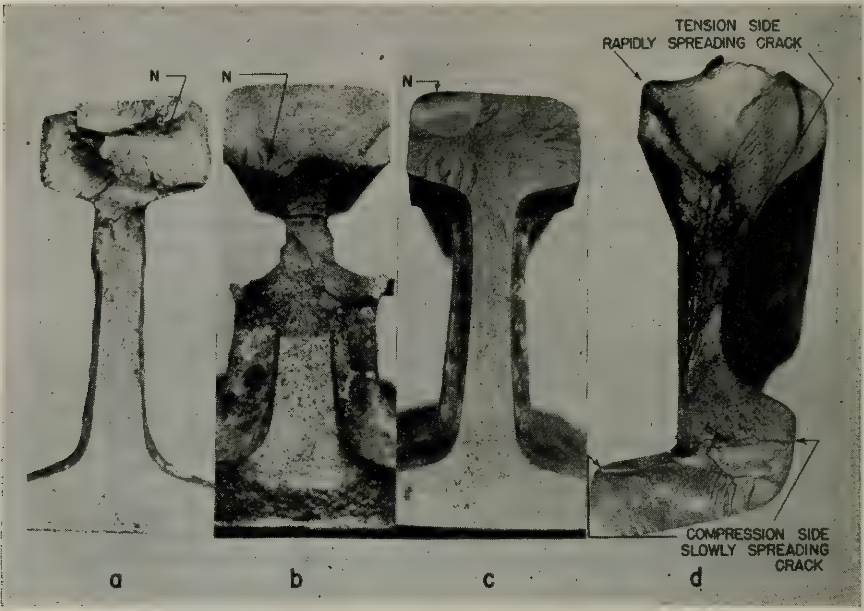

Fig. 4. Typical Fractures of Welded Joint Specimens in Rolling-Load Test.

a. Transverse fissure in head. Fissure started at N, and fracture occurred after 1,216,300 cycles of a 40,000-lb. wheel load.
b. Fissure started at N near junction of web and head, just outside the weld. Fractures occurred after 1,378,100 cycles of a 55,000-lb. wheel load.
c. "Fatigue" failure by spreading crack starting at N near corner of tread of rail. Crack started in coarse transverse grinding marks left on head of rail. Failure occurred after 650,000 cycles of a 75,000-lb. wheel load.
d. "Fatigue" failure of joint bar starting at upper and lower fishing surface after 56,100 cycles of a 75,000-lb. wheel load. Bending moment 900,000 in.-lb.

The specimen is so placed that the gap between the rails is at the edge of the block on which the rail rests and the path under the wheel load extends from this point to a point an inch or two from the free end of the specimen, which is mounted as a cantilever.

The rail joints with joint bars were placed in the machine the same way as the rail specimens. It is recognized that this throws tensile stress to the top of the joint bar and compressive stress to the bottom and that the cycle of the stress is quite different from that which has to be withstood by the joint bar in service. However, it was felt that the best comparison of strength under repeated load would be obtained by subjecting welded joints and joint-bar joints to the same testing conditions, namely, a cycle of bending moment varying from zero to maximum, with tension on the top side and compression on the bottom of the specimen.

The joint bars used in the test specimens were of heat-treated steel, and bars from the same lot were used for the 112-lb. joints. The joint bars for the 131-lb. rails were from two lots. It is recognized that there would be a wide difference between strength of different joint bars with different heat treatments and also that variations of bolt tension may produce wide differences in fatigue strength, as Professor Talbot's investigation has shown. These tests may be considered as representing test joints with a joint bar made of strong steel, carefully fitted to the rail and with a uniform bolt tension carefully maintained. (Note: The test results for the two lots of 131-lb. joint bars fall on the same curve in Fig. 3). This would seem to represent good practice in joint bars. Perhaps it might be considered that the joints with joint bars were made up with care corresponding to the care with which the welded joints were made. In any event the values from the few tests which it has been possible to make thus far should be regarded as indicative of general ranges of figures rather than a basis for sharp comparisons of strengths.

10. **Fatigue Failures in Joint Bars.**—In the joint-bar joints the final failure was always by a fatigue crack on the tension side. In one or two cases it was observed that fatigue cracks *started* on the compression side but progressed very slowly. In some cases the fatigue cracks on the compression side appeared first, and were followed by rapidly spreading cracks on the tension side. This is in agreement with the cracking observed in some joint bars in service. However, as is commonly assumed today, a fatigue crack starts under repeated shearing stress and tends to spread most rapidly under tensile stress. In view of this the behavior of joint-bar test joints is quite natural. Shearing stress is very nearly as severe on the compression side of the bar as on the tensile side. There is no reason why a crack could not be expected to *start* under either compression or tension. However, the rate of spread of the crack is distinctly diminished by the closing up of the crack on the compressive side while on the tension side there is a tendency for it to open. (See Fig. 4 (d)).

11. **Results of Rolling-Load Tests.**—As has been previously noted the number of rolling-load tests which have been carried out is relatively small. The endurance limits which have been determined must be regarded as at best only roughly approximate. In a general way it may be said that in the rolling-load tests so far carried out, the electric butt pressure welds seemed to develop strength almost, if not quite, up to that of the rail itself; the gas pressure welds were but little, if any, inferior to the electric butt pressure welds; the Thermit weld specimens and the joint-bar specimens had almost the same strength; and the gas fusion welds tested showed lower strength than the joint-bar tests. Table 1 shows results of rolling-load tests.

12. **Bend Tests on Rail Joints.**—Table 2 gives the results of bend tests on welded-rail specimens made up to date. The testing rig for bend test is shown in detail in the First Progress Report and all the specimens were tested under a 64-in. span with two equal loads spaced 6 in. either side of the center of length of the specimen. Thus the middle 12 in. of length of the specimen was under uniform bending. In Table 2 the maximum load before failure would be an indication of the strength of the joint, while the energy for fracture is taken as a measure of its toughness. The deflection at failure might be taken as a measure of its static ductility. It will be noted that the electric pressure weld and the gas pressure weld actually developed a higher load than a minimum value for crack-free rails tested for the Rails Investigation. They also developed higher energy for fracture in 131-lb. specimens. It is noted that the joints with joint bars developed a high amount of energy for fracture.

13. **Bend Tests and Rolling-Load Tests as Criteria of Strength of Joint.** In the study of fatigue of metals it has been found by many investigators that for many methods there seems to be a correlation between tensile strength and fatigue strength. A study of the results of rolling-load tests and bend tests was made to see whether any such correlation can be traced in the joints tested. It was found that the data were not sufficient nor the results consistent enough to justify any precise quantitative correlation, but the relative order of results for the two tests is shown graphically

TABLE 1

ENDURANCE LIMITS FOR 2,000,000 CYCLES OF ROLLING WHEEL LOAD FOR WELDED RAIL SPECIMENS, RAIL SPECIMENS WITHOUT WELDS AND SPECIMEN JOINTS USING JOINT BARS

During test head of rail subjected to cycles of tensile stress varying from zero to a maximum

Type of Joint	At Endurance Limit				Rolling-load Strength Ratio*	Remarks
	Wheel Load, lb.	Maximum Moment, in.-lb.	Maximum Flexural Stress lb. per sq. in.	Maximum Shearing Stress lb. per sq. in.	percent	
Joints with 112-lb. Rails						
Rail without weld	63,000	756,000	42,000	25,600	100	Based on bending moment
Rail with joint bar	41,700	510,000	(1)	(1)	66	Based on bending moment
Gas fusion weld—Process A	36,000	360,000	20,000	11,700	51	Based on wheel load, failed by internal fissure
Thermit weld—Process C	44,000	440,000	24,300	14,400	58	Based on bending moment
Gas pressure weld—Process E	55,000	550,000	30,600	17,900	73	Based on bending moment
Joints with 131-lb. Rails						
Rail without weld	(2) 79,000	(2) 948,000	(2) 42,000	24,200	100	Based on bending moment
Rail with joint bar	60,400	725,000	(1)	(1)	76	Based on bending moment
Gas fusion weld—Process B	20,000	200,000	8,800	6,100	25	Based on wheel load; failed by internal fissure
Thermit weld—Process C	55,000	550,000	24,400	17,000	70	Based on shearing stress; Web failure.
Electric pressure weld—Process D	More than 75,000	More than 750,000	More than 33,100	More than 19,500	More than 77	Based on bending moment
Gas pressure weld—Process E	More than 75,000	More than 750,000	More than 33,100	More than 19,500	More than 77	Based on bending moment

* Ratio of (Endurance Limit for specimen) to (Endurance Limit for Rail without Weld).

(1) Flexural stress in joint bars not computed; joint bars and rails made of different strength stee

(2) Estimated on the assumption that 131-lb. rail will develop as high flexural stress at endurance limit as 112-lb. rail. Maximum load which can be applied to machine, 75,000 lb.

TABLE 2

RESULTS OF BEND TESTS OF WELDED RAIL SPECIMENS, RAIL SPECIMENS WITHOUT WELDS AND SPECIMEN JOINTS USING JOINT BARS

Specimens were tested head-down unless otherwise noted

Specimen		Maximum Load before Fracture, lb.	Energy for Fracture, ft.-lb.	Deflection at Fracture, in.	Bend-Strength Ratio* percent	Remarks
Number	Classification					
	Joints With 112-lb. Rails					
....	Rail without weld**	225,000	75,000	4.0	100	
....	Joint with joint bar	151,100	193,500	20.0	67	
....	do. (tested head-up)	154,400	69,300	6.8	....	No head-up tests of rail without weld for comparison
W 4	Gas fusion weld—Process A	124,200	4,300	0.7	55	
W113	Gas fusion weld—Process B	140,500	6,900	0.9	62	
W253	Thermit Weld—Process C	193,900	23,370	2.1	86	
W404 W405	Gas pressure weld—Process E	228,400	57,800	3.9	101	Average of two tests
	Joints With 131-lb. Rails					
....	Rail without weld**	300,000	100,000	5.0	100	
....	Joint with joint bar	201,200	111,200	9.2	67	
....	do. (tested head-up)	202,700	42,300	3.3	....	No head-up tests of rail without weld for comparison.
W 22	Gas fusion weld—Process A	168,500	7,360	0.5	56	
W105	Gas fusion weld—Process B	79,400	867	0.2	26	
W203	Thermit weld—Process C Lot 1	231,500	22,200	1.65	77	
W223 W226	Thermit weld—Process C Lot 2	254,000	33,800	2.2	85	Average of two tests.
W311	Electric pressure weld—Process D	315,000	121,500	6.0	105	
W451 W452	Gas pressure weld—Process E	320,900	177,800	7.9	107	Average of two tests.

* Ratio of (Maximum load for specimen) to (Maximum load for rail without weld).

** Values for rails without welds taken from records of bend tests made by the Rails Investigation. Minimum values for crack-free rails recorded here.

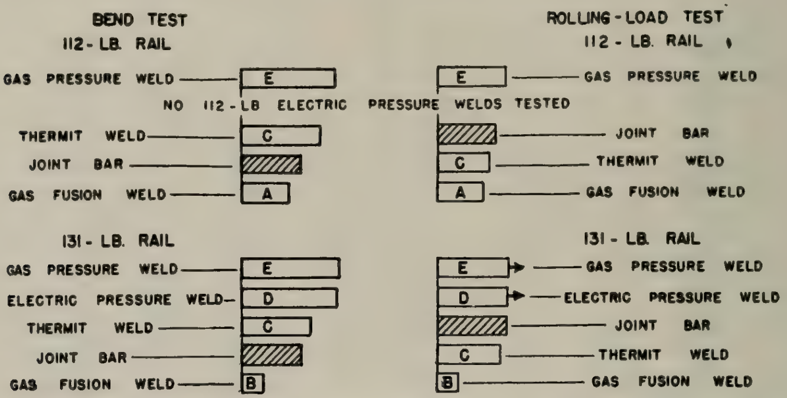

Fig. 5. Relative Strengths of Joints as Shown by Bend Test and Rolling-Load Test.
Letters on bars designate welding process.
Strength of Thermit weld joints in 131-lb. rails based on average for two lots of specimens.

in Fig. 5, in which the lengths of bars are proportional to the average strength ratios found. Attention is called to the fact that rolling-load tests for Processes D and E (131-lb. rail) merely indicated values greater than a certain amount. This is shown by arrows attached to the bars. An interesting fact in connection with this figure is that the bend tests and the rolling-load tests arranged the different types of weld in the same order of merit. It may be added here that taking both the bend tests and rolling-load tests into consideration it seems best to regard Processes D and E of so nearly equal value that a discrimination can not be made between them at present.

The correlation between order of merit as shown by the bend tests and that shown by the rolling-load tests is interesting. In view of the desirability of a reliable acceptance test for welded-rail joints further experimental study seems worth while. However, it would be unwise to conclude that such a correlation has been definitely established by these relatively few tests.

14. **Proposed Study of Welded Rail Failures in Service.**—A proposed questionnaire on the behavior of welded rails in service has been submitted to the Advisory Committee on Continuous Welded Rail with the request that some action may be taken so that this questionnaire or some other form may be sent to the railroads having welded rail in track. It would afford a source of systematic information on welded joint behavior in service, covering such items as first cost, maintenance cost, riding qualities, wear, and failures. At best, the laboratory tests of the strength of continuous welded rails indicate the order of magnitude of strength which may be expected as compared with the strength of rails without weld or with the strength of joint-bar joints in rails. Variations due to service conditions and variations in quality of the weld in joints made would have to be studied through service tests.

III. Metallographic Tests

By R. E. Cramer, assisted by E. C. Bast

15. **Second Lot of Thermit Welded Joints.**—During the past year metallographic studies have been made on a group of Thermit rail joints welded in May 1939. These welds differed from previous Thermit welds studied in two respects. First, the

molds had been changed to prevent the trapping of slag and loose mold sand at the junction of the molten weld metal and the rail steel near the lower portion of the rail head. Second, these welds were not post heated or given the strain relief heating to 1,100 deg. F. as were the previous Thermit welds.

16. **Hardness Tests, Etch Tests and Metallographic Examination.**—The rail heads in the test joints furnished were prepared for Rockwell "C" hardness tests over three areas: (1) on the side of the head, (2) on a horizontal surface 3/16 in. below the tread of the rail, and (3) on a horizontal surface 3/16 in. above the junc-

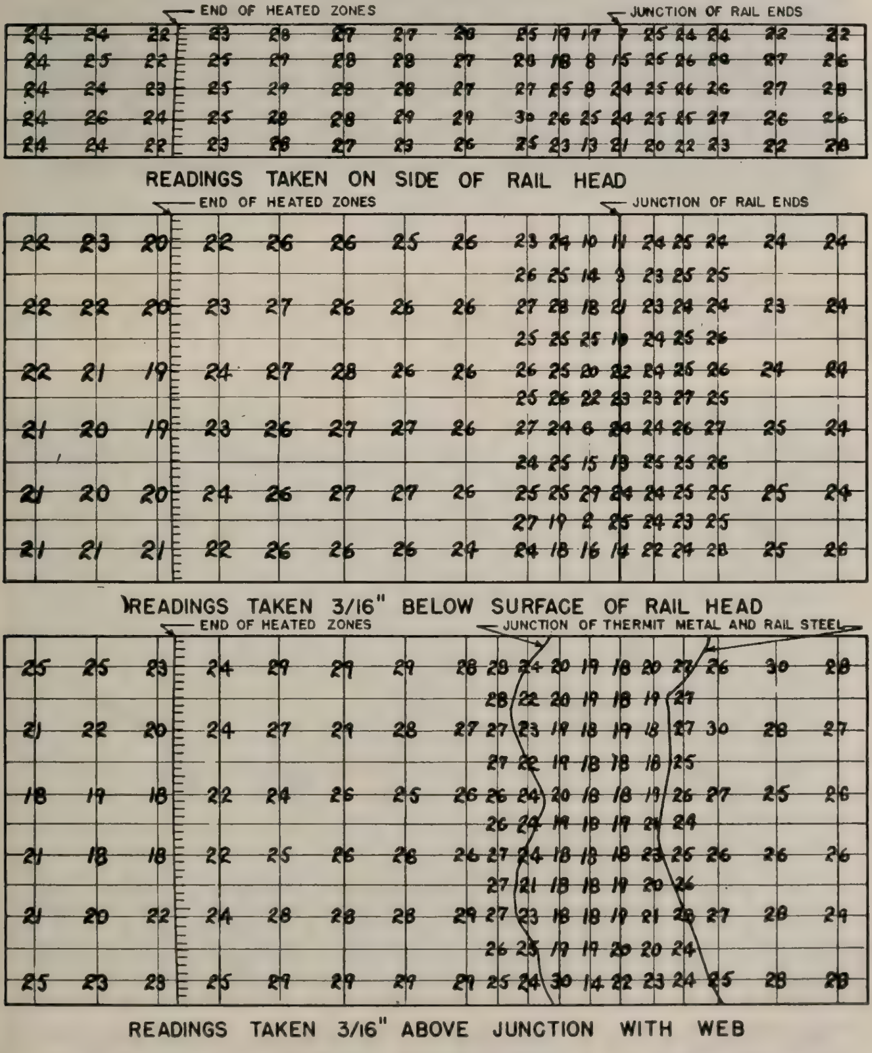

Fig. 6. Hardness Tests on Welded Rail Joint Made by Metal and Thermit Corporation New Type Weld No. W220. 131-lb. Section. Rockwell C Scale.

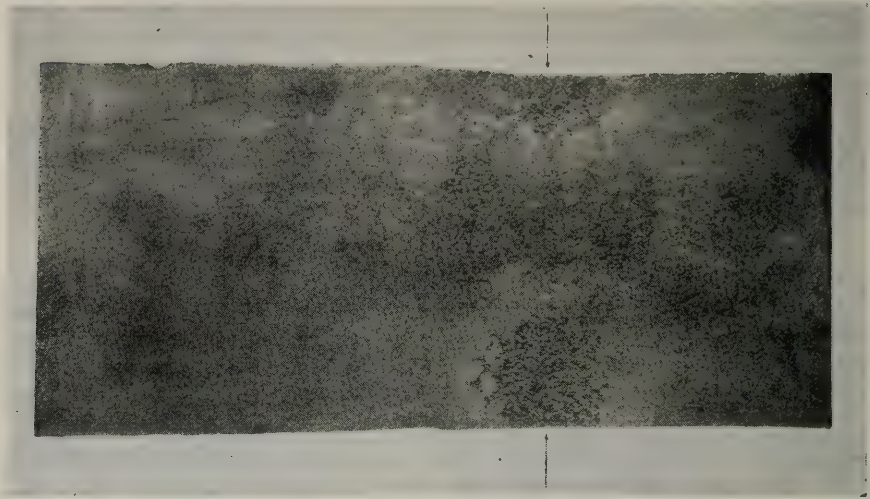

Fig. 7. Etched Horizontal Section of Weld ⅛ Inch Below the Tread.

Three-fourths natural size. Etched with hot Hydrocholoric Acid. The acid has brought out marks at both sides of the head at the junction of the rail ends. These marks are caused by oxide at the grain boundaries, as shown in Fig. 8.

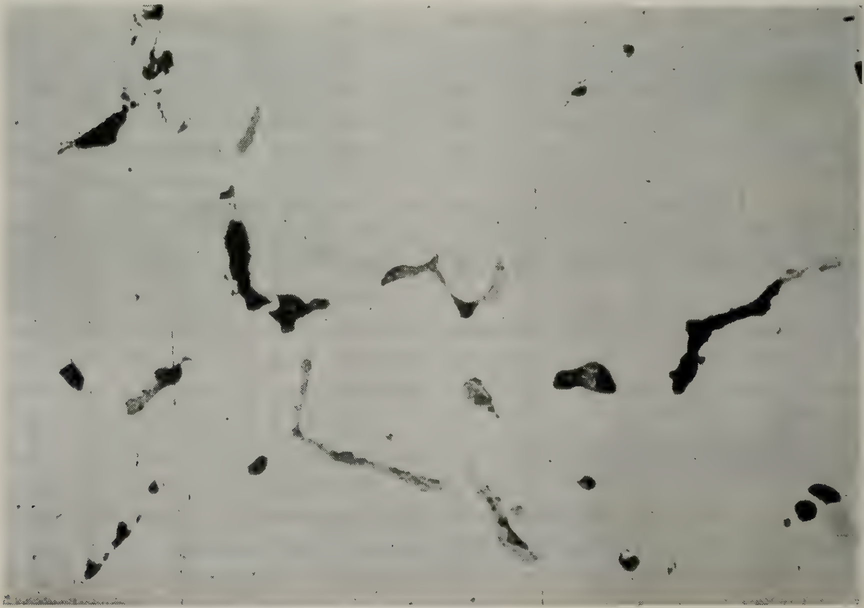

Fig. 8. Photomicrograph of Metal Showing Oxide Inclusions at Grain Boundaries. Magnification 80 X. No Etch.

Oxide inclusions appear as gray areas. The black areas are pits where the oxide has dropped out during polishing of the specimen.

tion of head and web. Typical Rockwell "C" readings are shown in Fig. 6. The hardness surveys show a few spots where the diamond brale of the Rockwell-tester hit either gas pockets or inclusions on the side of the head and also some spots where this same action occurred on the horizontal slice 3/16 in. below the tread of the rail. These spots are indicated in Fig. 6 by the Rockwell "C" numbers of 3, 6 and 8. In general, the hardness numbers near the junction of the rail ends approach in magnitude the hardness numbers of the steel outside the heated zone.

A six-inch section of the rail head, including the junction between the rails, was sliced into five horizontal slices and etched in 50 percent hydrochloric acid. Figure 7 shows the under side of the top slice, which was taken about ⅛ in. below the tread of the rail. Along both sides of the head at the weld region, the acid has brought out markings which look like cracks. However, microscopic examination shows that these markings were caused by the metal having been burned during the welding operation. This action deposited iron oxide at the grain boundaries. The oxide is dissolved by the etching acid. Figure 8 is a photomicrograph of the metal in this area, showing the gray inclusions of iron oxide along the grain boundaries. Some of the oxide dropped out during the polishing of the surface of the specimen, leaving pits which show black in the figure.

IV. Mechanical Tests of Specimens From Welded Joints

By S. W. Lyon

17. **Significance of Mechanical Tests of Specimens from Welds.**—In general, mechanical tests of specimens from welded-rail joints give a measure of the quality of the metal in the joint rather than a measure of the strength or toughness of the joint as a whole. In some cases, doubtless, mechanical defects were present in the small specimens cut from various parts of welded rail. But in general these tests would give an idea of the quality of the material itself when undamaged by mechanical defects—cracks, notches and other "stress raisers."

18. **Strength, Ductility and Toughness Tests of Specimens from Welds.**—The tests used to give some idea of the mechanical properties of the metal in the welds included, tension tests, fatigue tests and tension-impact tests. The tension test gives a measure of the static strength and static ductility of the material; the fatigue test gives some idea of the strength of the specimen under repeated stress; and the tension-impact test gives some measure of a combination of strength and ductility which is designated as "toughness." The specimens used are shown in Fig. 9. Tension tests were made in an Olsen screw-power testing machine using Robertson shackles to hold the specimens; fatigue tests were made in small rotating-cantilever machines which subjected the specimen to a complete reversal of flexural stress during a cycle of stress (one revolution of the machine), and tension-impact tests were made in a Charpy impact machine, fitted with a Lyon tension attachment.

Approximately 725 tensions tests, 1,280 fatigue tests, and 650 tension-impact tests have been made. Figures 11, 12 and 13 show the results of these tests.

19. **Quality of Metal in Different Parts of the Welded Joint.**—The etch tests (See Chapter III, page 746) made on different portions of the rail yielded etch patterns which show in a general way areas of section occupied by weld metal, metal affected by the heat of welding, and unaffected rail steel, as shown in Fig. 10 a. Groups of specimens were cut from the head, the web, and the base of joints, and in each

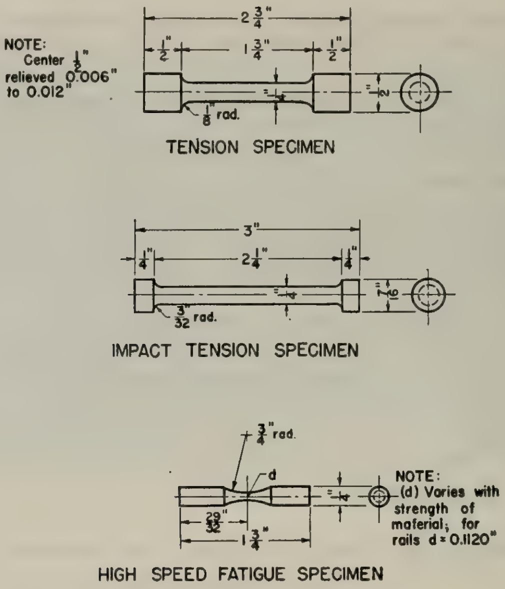

Fig. 9. Types of Specimens for Mechanical Tests of Welded Joints.

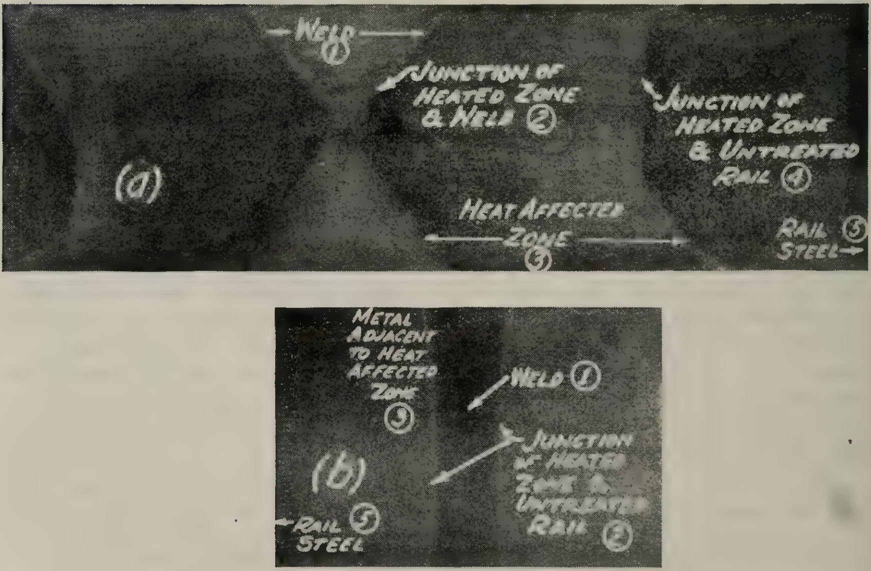
Weld ①
Junction of Heated Zone & Weld ②
Junction of Heated Zone & Untreated Rail ④
(a)
Heat Affected Zone ③
Rail ⑤ Steel
Metal Adjacent to Heat Affected Zone ③
Weld ①
Junction of Heated Zone & Untreated Rail ②
(b)
Rail ⑤ Steel

Fig. 10. Sections of Rails Welded by Processes A and D.

Etched to show extent of heated zone and location of various zones from which mechanical test specimens were machined. Approximately half natural size. Etched with Ammonium Persulphate.
(a) Gas Fusion Weld—Process A
(b) Electric Pressure Weld—Process D.

group specimens were cut from five "zones": (1) weld metal, (2) junction metal between weld metal and heat-affected metal, (3) heat-affected metal, (4) junction between heat-affected metal and rail steel, and (5) unaffected rail steel.

In this connection, as shown in Fig. 10 b, it may be noted that for the electric pressure weld (Process D) in which no metal is added during welding, and in which the heat-affected zone is very narrow, the system of zone designation as used eliminates specimens from Zone 4.

20. **Results of Mechanical Tests of Specimens.**—Figure 11 shows the results of mechanical tests of specimens cut from the rail head. In this series specimens were actually taken at each of either two or three horizontal layers in the head. The value reported is for that layer whose average value was lowest.

In the case of specimens from the web and from the base, only one layer of specimens was taken,—vertical in the web and horizontal in the base. In Fig. 11 the tensile strength seemed lowest in Zone 2, the junction metal between weld and heat-affected metal. However, for the 131-lb. rail, Processes C and D, the tensile strengths seem to be about equal to that of the rail steel, Zone 5. The endurance limit seemed to be slightly lower in the Zone 1, weld metal, and this was in general true both for the 112-lb. and 131-lb. rails, and the endurance limit of the rail steel, in general, was higher than that for the weld metal. The ductility and toughness were in general lowest in Zone 2, the junction metal between weld and heat-affected metal. Values of elongation, reduction of area, and energy for fracture (impact-tension values) were lower for weld metal than for rail steel, except for Process D, in which weld metal and rail steel showed nearly equal values for ductility and toughness.

Considering the results of specimens cut from the web, reference to Fig. 12 shows that the tensile strength in general is about equal in Zone 1, weld metal, and Zone 2, junction metal between weld metal and heat-affected metal. These values for Processes A and B are distinctly below those for rail steel. For Processes C and D the values are about the same as those for rail steel. For Process E, 131-lb. rail, the figures seem to be somewhat lower than for rail steel. The endurance limit is also lowest in Zones 1 and 2, and in all cases seems somewhat lower than for rail steel. The values for elongation, reduction of area and toughness are lowest in Zones 1 and 2, and for Processes A, B and C they are distinctly below the values for the rail steel. For Process D the results are slightly below the values for rail steel except reduction of area, which is about equal to that for rail steel. For Process E the data are incomplete, but for the 112-lb. rail the elongation and reduction of area are about equal to that of rail steel while for the 131-lb. rail and all tension-impact values the toughness is distinctly less.

Figure 13 gives a summary of the values for specimens cut from the base of the rail. The values of tensile strength again seem in general to be smallest in Zones 1 and 2. For Processes D and E the tensile strength seems to be equal to, and in some cases slightly above, that for the rail steel. For Processes A, B and C it is distinctly lower than that for the rail steel. The endurance limit is also lowest at Zones 1 and 2. In general, none of the fatigue tests show results quite up to the fatigue strength of the rail steel, although Processes D and E and the 112-lb. rail, Process C, approach that value. The ductility and toughness tests of material in the base again give minimum values for Zones 1 and 2. And again Processes D and E approach or equal the value for rail steel, and Processes A, B and C give results distinctly below. For the tension-impact results for Zones 1 and 2 it is again noted that values for Processes D and E approach (but in this case do not equal) values for rail steel, while for Processes A, B and C, values are lower than for rail steel.

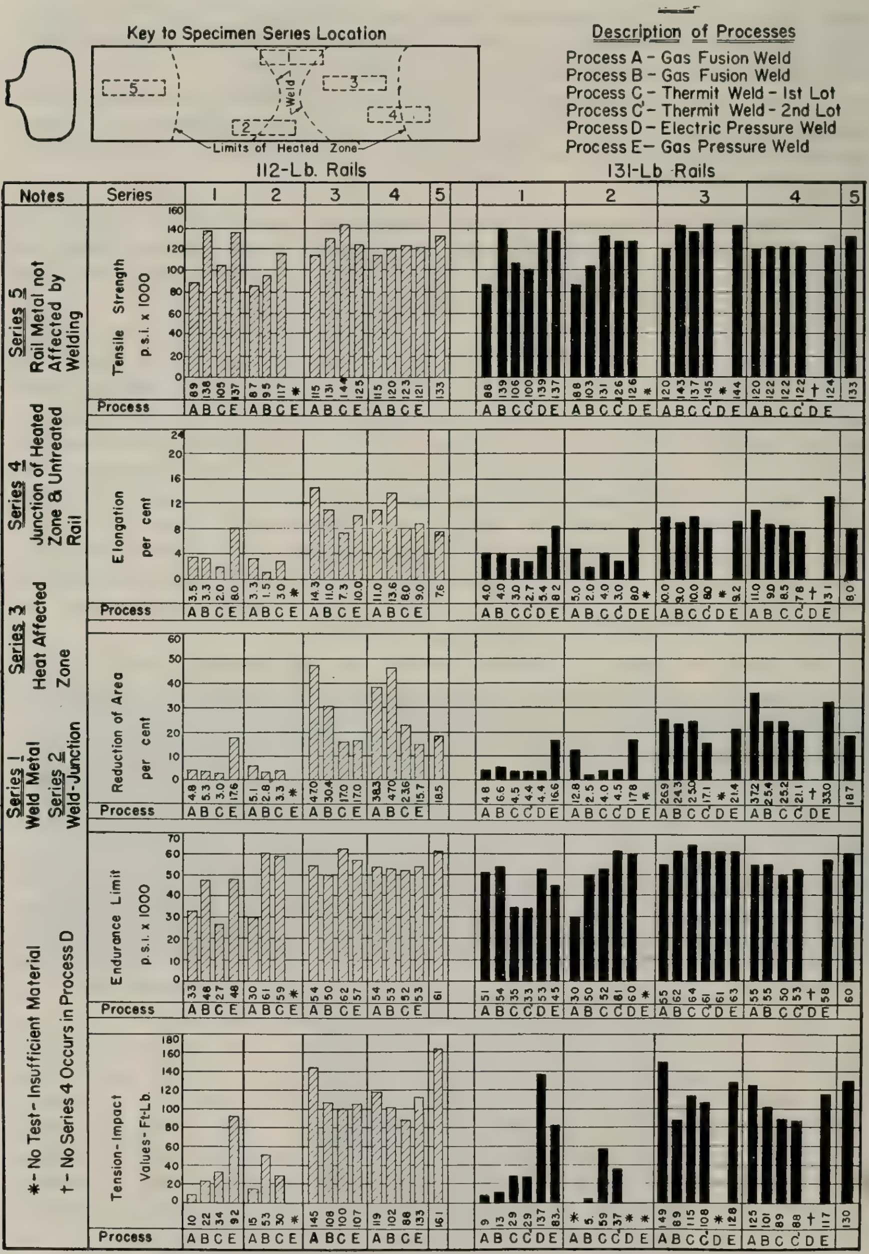

Fig. 11. Summary of Results of Mechanical Tests on Welded Rail Joints. Specimens Cut from Head.

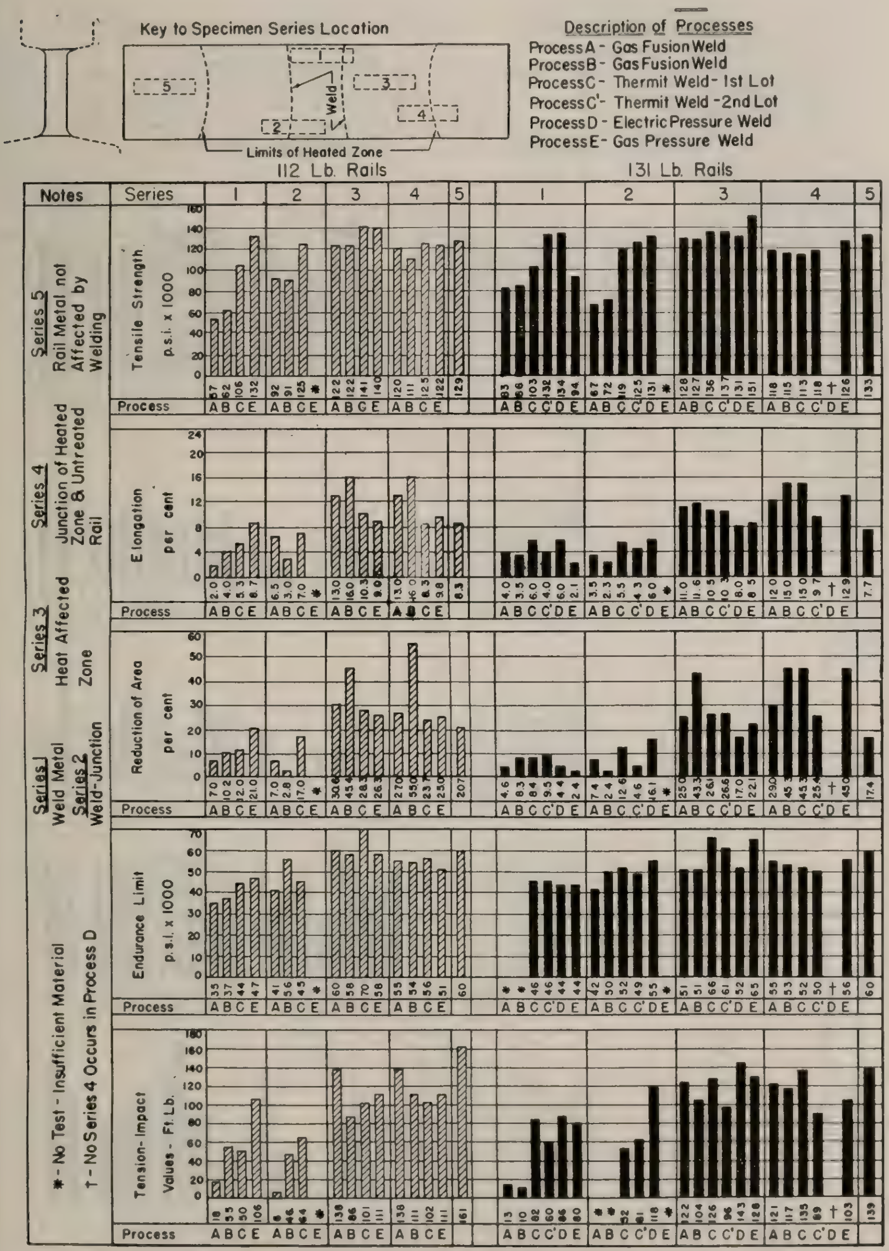

Fig. 12. Summary of Results of Mechanical Tests on Welded Rail Joints. Specimens Cut from Web.

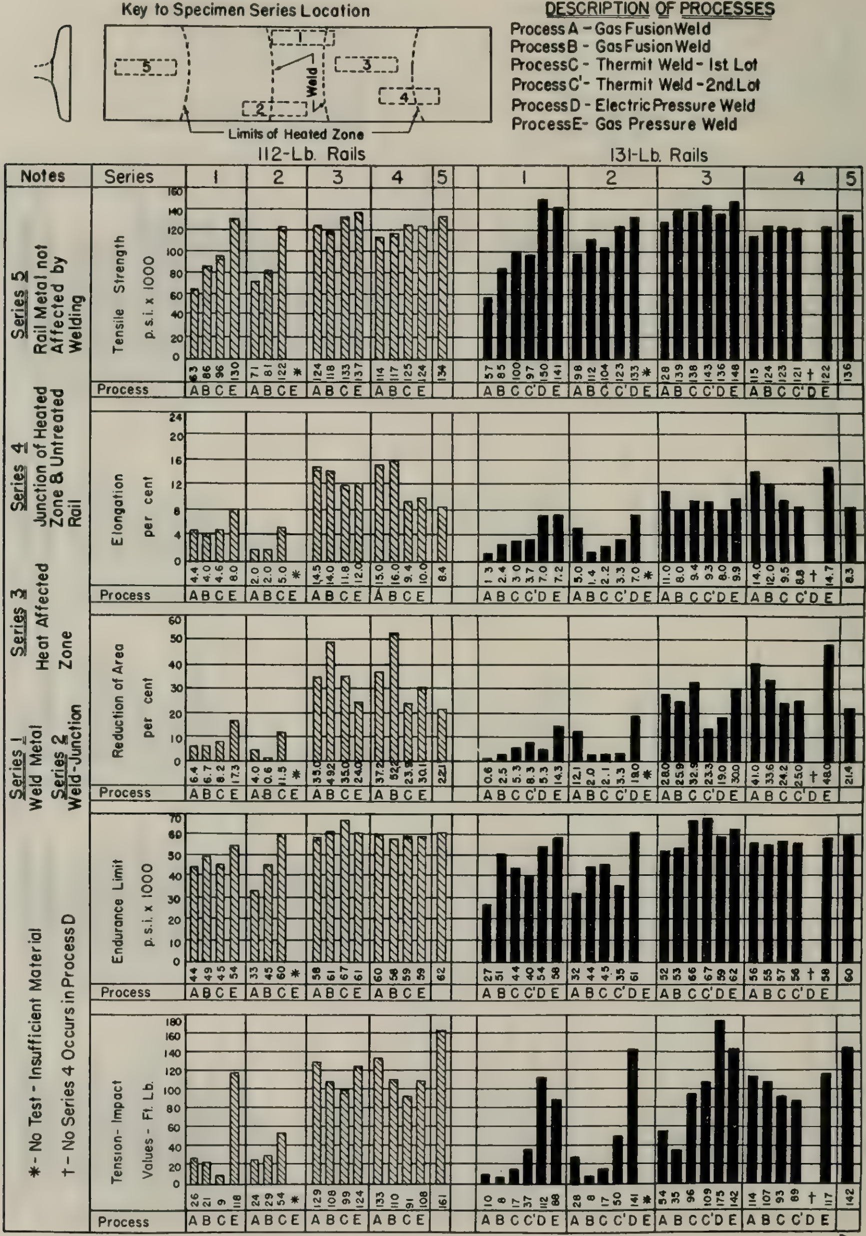

Fig. 13. Summary of Results of Mechanical Tests on Welded Rail Joints. Specimens Cut from Base.

21. **Specimen Tests Results as Indexes of Quality of Joints.**—As pointed out previously, the specimens cut from welded joints indicate qualities of metal rather than of the welded joints. Such factors as irregularities of outline at welds, minute cracks, and other mechanical "stress raisers" would not play much part in the tests of small specimens cut from the joint, machined to shape, and given a smooth finish. However, a comparison of the results of specimens tested with the results of rolling-load tests of joints do show various signs of the effect of poor metal on the strength of the joint as a whole. Evidently mechanical tests of specimens cut from the joint furnish one source of information concerning the strength of the joint. However, this information must be amplified by appropriate tests of the joint as a whole,—and, as in the First Progress Report, we may note that service records will furnish the final criterion.

PROCEEDINGS

Report of the opening session of the convention on Tuesday morning, March 12, 1940; the closing session on Thursday afternoon, March 14; and other business not related to the presentation of the committee reports.

Address by Judge R. V. Fletcher

Reports of the Secretary and the Treasurer

Discussions of committee reports

Opening Session, Tuesday Morning, March 12, 1940

The forty-first annual convention of the American Railway Engineering Association was called to order in the Grand Ball Room of the Palmer House, Chicago, Ill., by the President, Mr. E. M. Hastings, chief engineer, Richmond, Fredericksburg & Potomac Railroad, Richmond, Va.

President Hastings: This is the Forty-first Annual Convention of the American Railway Engineering Association. It is now declared open for business. This convention is also the annual meeting of the Construction and Maintenance Section, Division IV—Engineering, Association of American Railroads, the meetings being concurrent.

The first order of business is the reading of the minutes of the last annual meeting. Inasmuch as these minutes have been printed and a copy furnished to each member, unless there is objection, the reading of the minutes will be dispensed with. As there is no objection, they stand approved as printed.

Address of President E. M. Hastings

Time marches on. To one who has had the great honor to serve as president of the American Railway Engineering Association time does not seem to march but rather seems to be in full flight; a year passes and is gone almost before one becomes thoroughly familiar with the duties of the office and is able to grasp the opportunities that are slipping by in almost a continuous stream, challenging thought and action and calling for the best that can be given. When I stood on this platform last March and received the token of office from my distinguished predecessor, Fred Morrow, I thought a year was so long a time that there would be sufficient and to spare, but here we are, a year gone, yet still so much to be done. Nothing unusual about that you say, no, nothing unusual, but we need to face the every-day facts in order to qualify ourselves properly to fill the place which each one of us may have and to do the share of the world's work that is ours to perform.

The closing year in our association life has been one filled with the usual activities and marked by many accomplishments that will be made more evident to you as you hear the reports, conclusions and information presented by the committees during the next three days. Having always behind them the splendid bulwark of recorded work of the Association, built up through years of painstaking thought and labor, you will find on hearing and studying the reports of this year that the committee workers have pushed forward seemingly inspired and challenged by the record of the past to record for the Association even greater accomplishments for the present and the future. If it is true that "What is past is prologue" then we are not too ambitious to expect the future to bring to our Association through its able membership that which will, added to the present accomplishments, challenge the future workers as we are challenged today.

Finances

The Association is in splendid condition financially, its investments are sound and the income during 1939 exceeded the expenditures by a reasonable amount; at the close of the year the total assets were slightly in excess of $85,000.

The membership during the recent years has not been showing growth for reasons familiar to all of you. It is hoped that there will be some growth in the years ahead as conditions generally improve, bringing an increase in engineering employment. There is another matter with reference to membership that I wish to present to you and that is opening the way to bring in the young men. Your Board of Direction has been studying this question during recent months and it is expected that a constitutional amendment will shortly be sent to the membership for vote providing for the creation of a Junior grade whereby a young man just out of college may be admitted as a Junior at a reduced annual fee and continued as such until he reaches an age that would permit him both from age and experience to be transferred to the Member grade. We have been losing the opportunity of bringing into our Association young men entering railway engineering upon graduation by having a minimum age requirement of 25 years. I strongly urge you to vote favorably upon such an amendment if and when it is presented to you.

The interest of engineering students in the AREA should be enlivened by the contacts they have with members of the Association. The Board of Direction has reestablished the Committee on Cooperative Relations with Universities; through this committee much can be done to place before the students the field of opportunity in railway engineering, and demonstrate the advantage and privilege of membership in the AREA.

In the matter of committee work the several committees have covered a wide field and made a fine contribution to the permanent records of the Association during the past year. The information presented and conclusions reached are worthy of greater attention than they receive, and again I say to you, as I have said in past years when presenting the report of the Standardization committee, you are not fulfilling your responsibility to your railroads or to your Association unless you study and use, wherever practicable, the recommendations of the Association as found in the Manual of Recommended Practice, and the information gathered and presented by the committees from year to year in *your* study and solution of the problems presented on your own railroad. The Manual is not used to the extent it merits or to which, by reason of its value to the railroads, it is entitled.

Work of Committees

I believe that further study should be given to the assignment of committee work looking to the setting up annually of preferred subjects on which the committees are to report and present recommendations to the annual convention; and the publication, without formal presentation to the convention, of the progress reports and those submitted for information only. With the number of committees which we have working and the great number of subjects assigned we have in recent years witnessed a marked reduction in the discussion of the material presented from the floor of the convention. This may be due to the volume of material presented and the lack of time. With fewer subjects presented to the convention for action more study should be given the subject matter prior to the convention and thus stimulate more discussion from the floor. I believe that in the end just as much would be accomplished for the permanent record and a greater number of the members would be familiar with it.

The publications of the past year compare well with those of previous years but I wish to direct your attention especially to Bulletin 412 of September–October, 1939, containing monographs by Professor Wilbur M. Wilson of the University of Illinois on "Design of Connection Angles for Stringers of Railway Bridges," and by Edwin F. Wendt on "Federal Valuation of Railroads."* These are ably prepared papers and most valuable additions to our publications. The paper by Past-President Wendt is a most comprehensive treatise giving the whole story of federal valuation logically arranged, and making a splendid record for reference.

Research Work

During the year I have been striving for a better understanding of the relationship of your Association, acting in its capacity as the Construction and Maintenance Section of the Engineering Division, to the Association of American Railroads. I think marked progress has been made. Early in the year the handling of research was revised on the recommendation of the General committee, Engineering Division, so that all matters of research financed by the AAR are now directed through a Research committee of the General committee and executed by the research engineer of the Engineering Division, working in cooperation with the committees interested. The Research committee consists of two members from the Construction and Maintenance Section, they being the president and first vice-president of the AREA, one member from the Signal Section and one member from the Electrical Section. The president of the AREA being the chairman of the Engineering Division, is the chairman of the Research committee. Machinery has been set up whereby requests for research, when funds are needed, are submitted by the committees of any one of the three sections interested, the Construction and Maintenance, Signal or Electrical, to the Research committee and, if recommended by that committee, are passed on to the General committee and to the AAR for appropriation.

In the budget for 1940, approved and provided by the AAR, an item of $4,000 was authorized for the impact studies which your Special Committee on Impact desires to carry on. This work has been started under the direction of the Committee on Impact and the research engineer. Appropriations for 1940 have been made by the AAR for the continuation of the work of the Stresses in Track committee, the Rails Investigation and other work as heretofore.

I wish here to record my appreciation of the fine cooperation and assistance given by the vice-president of the AAR, first by the late J. W. King and, following his untimely death, by Mr. C. H. Buford; and also by Mr. L. E. Dale, transportation engineer. It has been a real privilege to have had the opportunity of working with them. I trust that there will be in the future an expanding influence by the AREA in the affairs of the Engineering Division and the Association of American Railroads.

The secretary's office has been a bulwark of strength to your president during the year; if we have accomplished things that are worth while it has been largely due to the fine work of Secretary Lacher and his staff. The Board of Direction has given support, encouragement and cooperation in its administration and direction which I gratefully acknowledge; it has been an inspiration to work with these earnest men.

You may forget a good many of the things I have said just now, in fact most of them, unless you take the printed pages later and read them, but if you do forget those things, I am asking you if you will at least turn over these two closing paragraphs carefully in your mind and store them away to find if there is in them that which we need to think about in these days in order to guide us into wise directions and bring about wise conclusions.

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* Reprinted on pages 889 and 905, respectively, of this volume of the Proceedings.

I know of no group having higher qualifications for real citizenship than the group I address this morning. I know of no need facing this country at the present time greater than the need for real constructive citizenship. Therefore, I am appealing to you not to be satisfied with just following your profession, just working for your railroad, just thinking along technical lines or just following along with the crowd. Rather, I am urging you to face the undeniable fact that change is taking place all over the world, and although change may be necessary in many places yet there are certain fundamental truths and principles upon which we have relied and builded through the years that must be preserved if we are to remain a free and happy people. Therefore, as a group of men and women with minds trained to seek the truth in scientific knowledge, we fail in what is expected of us if we do not extend our thinking and analyses into the fields of government and citizenship.

Over the arch at the entrance to the University of Virginia is this inscription, "Pass through this gateway and seek the light of truth, the way of honor, the will to work for men". In the affairs of the world as well as the affairs of this and our neighboring nations, we are, it seems to me, standing at a gateway. It may be one of opportunity and promise depending largely upon each one of us and the way we conduct ourselves and our thinking. Should we not then so order our lives, our work, our contacts, our influence that we constantly live and strive to seek the light of truth, the way of honor and the will to work for men? (Applause)

President Hastings: This Association also functions as the Construction and Maintenance Section of the Association of American Railroads, and it reports to the vice-president of the Operations and Maintenance Department. It is our privilege this morning to hear from Vice-President C. H. Buford of the Operations and Maintenance Department of the Association of American Railroads. Mr. Buford is an engineer by training and experience, having been responsible for important construction work on the Chicago, Milwaukee, St. Paul & Pacific Railroad prior to entering the operating department. He was general manager of the western lines of that property at the time of his election to the vice-presidency of the AAR during the past summer.

It gives me a great deal of pleasure, gentlemen, to present to you Mr. C. H. Buford. (Applause)

Address by C. H. Buford

Vice-President, Operations and Maintenance Department, Association of American Railroads, Washington, D.C.

This is the first opportunity I have had to attend one of the annual meetings of the American Railway Engineering Association and I feel complimented by your kind invitation to address you. It is a rare privilege and an honor to be here to congratulate you on the results you have obtained and the reputation you have established in the past 40 years.

Your Year Book still lists a considerable number of living charter members, but 40 years is a long time, and the active personnel of your organization has almost completely changed in those years. Similar changes have taken place in the character of work you carry on, but like the changes in membership, the changes in subject assignments have been gradual.

In order to have a clear understanding of the extent to which your interests and activities have altered since your Association was organized, we should consider briefly the problems confronting you at the beginning of the present century.

Then and Now

In 1900, the railroads were sorely in need of both immediate and extensive development. This was brought about on account of the enormous growth of traffic following the long depression of the "Nineties", and by competition, which was forcing the construction of new main and branch lines into what was still undeveloped territory. This was the period that started the race between the length of side tracks and the length of trains which could be handled with locomotives of ever-increasing weight.

By 1920, conditions had changed to the extent that Congress embodied in the Transportation Act the requirement that railroads must obtain certificate of covenience and necessity before proceeding with the construction of new lines or extensions.

Today, the conditions are further changed. There is not only no restrictions placed on the building of additional facilities for competing forms of transportation, but also actual federal aid for most of it, with the net result that the transportation plant of the United States is being expanded at a rate that bears no possible relation to present or potential future needs.

The marked change in the railroad picture has had a profound effect on the problems of the engineer and, by the same token, on the field of usefulness of your Association. Formerly your main responsibility was to aid the engineer in his efforts to complete the construction of new or additional tracks in the shortest time, or in the solution of intricate problems growing out of almost hopelessly congested terminals. Money was plentiful and the slogan was "Speed".

Today, your problem relates to such matters as finding the most economical methods of maintaining existing tracks and structures or determining what types of construction can be maintained for the least money. You are engaged in a process of refinement and in investigations of methods and materials that will give us a safer plant for railway transportation.

You, as engineering officers of the railroads, are directly responsible and are held to account for the safety of track and structures. These tracks and structures are affected by the size and kind of locomotives and cars and the speed at which they are operated. These related problems demand cooperation, and I am glad to say that I have noted a wholesome trend toward a more sympathetic understanding between the Mechanical and Engineering divisions of the AAR. An evidence of this is found in the recently completed freight car truck tests in which your Division cooperated with the Mechanical Division.

The Place of the AREA

The AREA occupies a unique position. It is, first of all, an association of individuals who carry on voluntary committee work for the solution of problems in which they have a mutual interest. At the same time, it is a division of an Association of railway corporations. You have functioned very well in this dual capacity, and there is no question but that the results have been of great benefit to both you as individuals and to the railroads by which you are employed. However, it is well for you to bear in mind that even though you carry on your investigations as a voluntary association of individuals, you are representing the railroads of this country to a far greater degree than you may realize. The AREA enjoys a well earned reputation and its published reports carry a great deal of weight. I am not referring alone to the recommended practices appearing in your Manual, which must stand the test of approval by your conventions and review by the Association of American Railroads, but as well to those portions of your reports that represent merely the consensus of committees that prepared them.

Public authorities and others who read your reports will not always take the trouble to differentiate between what is merely an expression of opinion on the part of the committee and what bears the stamp of association approval. The mere fact that a statement appears in a report of the AREA will be reason enough for someone to cite it as authoritative if it happens to suit his purpose.

Just as you represent individual railroads in your regular employment, so, also, do you represent the railroads as a whole in the work you carry on for the AREA. In your relations with the public in either status, you may not always be acting in an officially authorized capacity. But regardless of this, what you do or say will be taken as representing the point of view of the railroads. So in your work with the AREA you are confronted with a responsibility which you must always bear in mind when you get to the point of putting your ideas on paper where all may read.

The Board of Directors of the AAR has appropriated almost $100,000 for your activities during 1940 and in this way indicates its appreciation of the work you are doing to improve the railroad plant and its service to the public. I want to thank President Hastings and the various committee chairmen and members for the cheerful and efficient way in which they have handled the Association's work in the past year.

What the Railroads Have Accomplished

As you have a long program before you I will not take up much more of your time, but I would like to talk for a few minutes longer about a part of our job that I do not believe we are doing as well or as often as we should. Yet it is important to the very future of the great industry with which we are directly or indirectly affiliated. Notwithstanding the remarkable improvements that have been made by the railroads in recent years, we still hear some criticism from day to day that the railroads are behind the times; that they are trying to do business today with a plant that has improved little since grandfather's day; that they are backward in research. Most of the people who make such remarks do so because they are ignorant of the facts. For example, six years ago there were about 40 air-conditioned passenger cars in the United States—all diners assigned to the more important trains. Today we have about 12,000 air-conditioned cars—coaches, diners, sleepers and lounges. These clean, quiet, comfortable cars are operated by the railroads and Pullman Company in regularly assigned through passenger service.

Six years ago, we had only a few thousand miles of passenger runs scheduled daily at a speed of 60 miles or more per hour. Today, we have about 55,000 miles of passenger runs scheduled at a mile a minute or more.

Six years ago there was not a single streamlined train in the United States. Today we have more than 100 sleek streamlined trains serving most of the larger cities and more will be added during the spring and summer.

In 1939 the railroads established the best general safety record in 50 years when the number of train accidents, as compared with the number of miles run by trains was the lowest on record.

Today's freight trains are hauling a larger volume of freight and handling it faster and safer than they did 10 years ago. This fact was forcefully demonstrated when, in September and October of last year, the railroads were called upon to handle the most rapid increase in freight business on record. It was done without congestion, delay or car shortage, because of better equipment and better methods. You can rightfully take pride in the amazing transportation performance that was turned in last fall, because the sort of work you do, day in and day out, contributed in no small measure to the ability of the railroads to meet successfully and completely this unprecedented situation.

All of the mentioned improvements and many more that will occur to you are the direct result of large capital expenditures, exhaustive studies and never-ending research. We cannot afford to let anyone continue to believe that the railroads have failed to modernize their plant or that they are laggard in research. Most people conceive of research as consisting of retorts, crucibles and instruments in the laboratory. They envision the research man as an individual attired in a smock and carrying on intricate and difficult work in a huge, mysterious building. They measure the results of his efforts largely by what they can see or by some revolutionary discovery that he may make during his studies.

Railroad research cannot be carried on in the same way as that of most other industries. It cannot be centralized in any one place, nor can it be confined to the laboratory or to any one class of investigator. A great deal of it must be done in the shop, on the track, in the trains and in all parts of the country under the most exacting service conditions.

It would be a waste of time for me to enumerate before this group what the railroads have done and are continuing to do in the way of research. You know, perhaps, better than anyone else to what great extent the railroads and the manufacturers of rail equipment are engaged in finding better ways and better equipment to do a better job of transportation. You know that millions of dollars are spent annually for this very purpose. But, unfortunately, most of our population knows little or nothing about these things, and the reason for their not knowing is because the officers and employees of railroads and the officers and employees of the companies that furnish us with the 70,000 different things we use, have not told them.

Public Must Be Informed

One of our big jobs is to impress on the public mind the immensity and value of our achievements and the rate of our progress. We must tell our story in simple and non-technical terms. It is a familiar one to us but it is brand new to others. When we start telling it in the effective way it should be told, I believe we will be amazed at the interest our listeners will show. Most people are interested in transportation and like to hear about it. Trains catch the public fancy as much today as they did years ago, and this works decidedly in our favor.

I know of no group of men who are better qualified and better equipped than you to tell the railroad story of achievement and progress. You know the facts better than anyone else, and you know the amount of labor, money and time that has gone into every railroad improvement. You know, too, what these things have meant not only to the railroads, but also to the economic and social welfare of the nation. You can, therefore, tell it with authority and effectiveness, and if you would at every opportunity, along with others who should, the people of this country would realize that the railroads are competent, efficient, progressive and are performing an outstandingly good job. When the people know the facts, they will be more likely to demand that government take the necessary steps to create a fair field in transportation and this is necessary if our railroads are to continue rendering the best possible service at the lowest real cost.

It is our responsibility to do our part in creating a better understanding and appreciation of railroads and what they mean to the prosperity and safety of this country.

President Hastings: We are very grateful, indeed to you Mr. Buford, for being with us this morning and bringing us this fine message.

The next order of business is the report of the Secretary and the Treasurer. Mr. Lacher, Secretary, will present these reports.

(The secretary commented briefly on these reports, which appear in full on pages 772 to 781, inclusive.)

President Hastings: Gentlemen, you have heard the reports of the Secretary and the Treasurer. What is your pleasure?

Mr. F. L. C. Bond (Canadian National): I move they be approved.

(The motion was seconded, put to a vote and carried.)

President Hastings: What we are about to do now, gentlemen, is not a matter of form and should not be considered as just one of those conventions. You have heard the secretary make reference to those who have passed on during the year that has just closed. That long list of names that is published on two pages of the secretary's report embraces the names of many of our dear friends, men with whom we have associated during the years with profit to ourselves and, I hope and trust, with joy to each other. I am just reminded at the moment of those very familiar and oft repeated lines of Longfellow when he wrote:

"Lives of great men all remind us
We can make our lives sublime,
And departing, leave behind us
Footprints on the sands of time."

Then he went on to say that other most profound thing and, I may say, eternal truth:

"Life is real! life is earnest!
And the grave is not its goal;
Dust thou art, to dust returnest,
Was not spoken of the soul."

Will the convention rise in tribute to these deceased members?

(Silent tribute to memory of deceased members.)

Remarks on Thursday Afternoon, March 14, 1940

President Hastings: At this moment I am not in very good shape to handle the convention. I haven't quite regained my equilibrium. At a luncheon meeting today, the Committee on Yards and Terminals, of which I have been a member for many years, presented me with a very beautiful silver tray. In addition to the inscription, it carries the personal signature of every member of the committee. I think that all of you will be sympathetic enough to realize that it will take a little while for me to recover my composure after such a presentation, realizing, particularly, that the token came from those men because of the long years of friendship and work that we have had together and because, for some reason or other, I don't know why it is, they seem to think a lot of Hastings.

Mr. C. H. Mottier (Illinois Central): I would suggest that Mr. Lacher read the inscription on the tray.

Secretary Lacher:

"Edgar Morton Hastings

President of the American Railway Engineering
Association
With admiration and affection from his
fellow members on the Yards and Terminals
Committee, March, 1940." (Applause)

Report of the Tellers

(Presented Wednesday Afternoon, March 13, 1940)

We, the Committee of Tellers, report the following as the result of the count of the ballots:

For President:

Geo. S. Fanning	930
Scattering	1

For Vice-President:

H. R. Clarke	928
Scattering	1

For Directors (Three to be elected):

A. A. Miller	555
G. P. Palmer	424
Armstrong Chinn	372
R. A. Van Ness	300
B. R. Kulp	292
W. M. Wilson	291
F. R. Judd	259
H. F. Brown	169
C. P. Richardson	157
Scattering	1

For Nominating Committee (Five to be elected):

G. L. Sitton	666
J. E. Teal	563
H. A. Dixon	560
L. L. Adams	531
G. A. Haggander	525
A. E. Perlman	469
L. P. Kimball	449
M. J. J. Harrison	308
H. G. Morgan	286
L. H. Laffoley	262
Scattering	1

Respectfully submitted,

THE COMMITTEE OF TELLERS,

R. C. Bardwell, *Chairman*
F. W. Alexander
J. C. Bradley
W. F. Cummings
W. T. Dorrance
H. F. King
H. E. Kirby
R. A. Morrison
F. E. Morrow
E. F. Salisbury
H. E. Silcox
C. A. Taylor
J. N. Todd
A. R. Wilson

Closing Session, Thursday Afternoon, March 14, 1940

Resolutions

(The following resolutions were adopted unanimously.)

Be it resolved, That the American Railway Engineering Association, in convention assembled, express thanks to C. H. Buford for his constructive message at the opening session of our convention and for his cooperation with our Association in his capacity as vice-president, Operations and Maintenance Department, Association of American Railroads.

Be it resolved, That the American Railway Engineering Association, in convention assembled, express its appreciation to the Western Railway Club for the privilege of joining in the meeting on Wednesday evening, in which we found much of interest in the description of the local transportation problems of the City of Chicago and in the progress that is being made in their solution.

Be it resolved, That the American Railway Engineering Association, in convention assembled, record its appreciation to Judge R. V. Fletcher for his constructive and challenging address at our luncheon, which address emphasized to our members the unfairness of the competition to which the railroads are subjected by other transportation agencies and stimulated action among our members individually in combating this condition.

Be it resolved, That the American Railway Engineering Association, in convention assembled, extend its appreciation to the National Railway Appliances Association for the constructive exhibit of materials and equipment applicable to the construction and maintenance of railway roadway and structures, presented concurrently with the convention, which exhibit has added much to the educational value of our meeting.

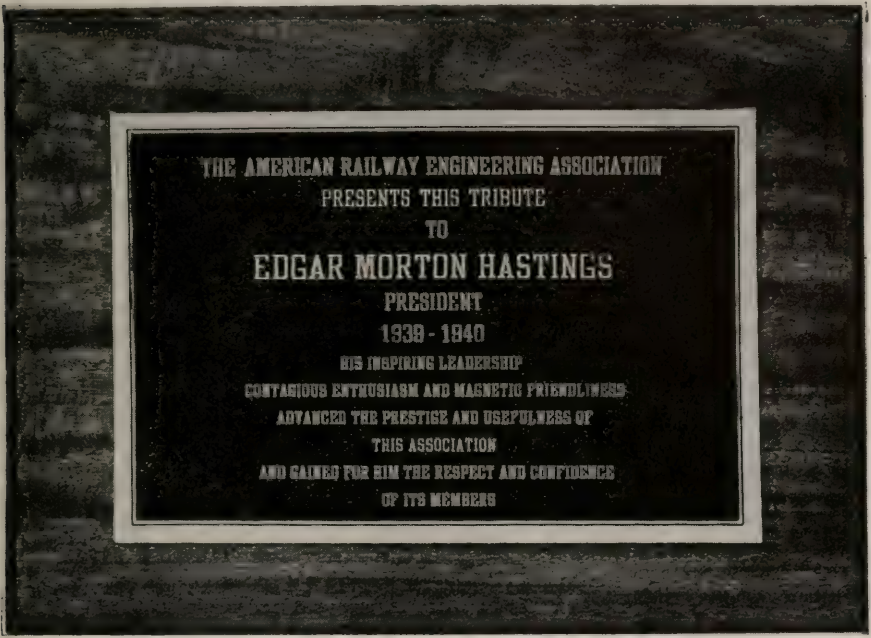
Presentation of the President's Plaque

Mr. F. R. Layng (Bessemer & Lake Erie): Mr. Hastings, in recognition of your splendid service to this Association, the members of the Association wish to record in permanent form their feelings in regard to your administration. Your leadership, your continuous enthusiasm and magnetic friendliness have advanced the prestige and usefulness of this Association and gained for you the respect and confidence of its members.

I take great pleasure in giving you this permanent record of our feelings in this respect. (Applause)

President Hastings: A lot of nice things have been said to me at this convention. It doesn't make any difference how much you may anticipate a thing—and I must say that I hoped I would receive one of these beautiful plaques—and you have everything planned and prepared in your own mind as to what you are going to say, when the event takes place and then you are presented with it, it is gone with the wind.

If I have been able to accomplish anything in the past year for the Association or in the years preceding this one, when I have worked with your committees and on the Board, it has not been due to any peculiar ability that I might have had, because I don't have it. It has come from the inspiration that has been given to me by the splendid men who compose this Association, and it has come to me in observing the leadership that has been given to you in the past years. I don't care if I live to be one hundred or more, I know that I will never in the future days find associations or friendships that can possibly equal those that I have found here and formed in your Association.



THE AMERICAN RAILWAY ENGINEERING ASSOCIATION
PRESENTS THIS TRIBUTE
TO
EDGAR MORTON HASTINGS
PRESIDENT
1938 - 1940
HIS INSPIRING LEADERSHIP
CONTAGIOUS ENTHUSIASM AND MAGNETIC FRIENDLINESS
ADVANCED THE PRESTIGE AND USEFULNESS OF
THIS ASSOCIATION
AND GAINED FOR HIM THE RESPECT AND CONFIDENCE
OF ITS MEMBERS

Plaque presented to President E. M. Hastings on March 14.

I have had real joy in working for you and with you, and I hope that I am going to be permitted to continue to work for you and with you in the years ahead. You have overwhelmed me with your kindness, your consideration, and I feel that you have honored me beyond anything that I could possibly have deserved. I thank you from the bottom of my heart. (Applause)

There is one other little thing I would like to say to you and that is that our registration has totaled 1,202 this year. Last year it was 1,029; in '38 it was 1,087. We have had a wonderful convention, a fine spirit everywhere, and the thanks for it are due to you members of this fine Association.

Installation of President Fanning

President Hastings: I will ask Past Presidents Armstrong and Wilson to escort the president-elect to the chair.

(President-Elect Fanning was escorted to the platform.)

President Hastings: Mr. Fanning, it is with very peculiar pleasure that I greet you here as these predecessors of mine and of yours have brought you to this platform. I am going to turn over to you the token of office, this beautiful gavel, which is yours.

As I present this to you, Mr. Fanning, I know that with it goes all of that fine spirit of loyalty and cooperation from the Association that has been given to me and all of the predecessors in office. In handing it to you, we know that you are going to carry on the work of this Association most ably, because we know and I know that you can do it.

Let me congratulate you. (Applause)

(President Fanning assumed the chair.)

President Fanning: For two years I have had the high privilege of serving under two presidents who have most ably advanced the American Railway Engineering Association in strength and prestige. With the benefit of their example and the help of officers, directors and members, I hope that I may carry on during the coming year.

Both Mr. Morrow and Mr. Hastings are blessed with a quality of tact, with which I find myself sadly lacking. To those of you who have misgivings as to what this new bull will do in the china shop of your precedent, may I say that if I break any china, I shall try to do it as quietly and gently as I can. (Laughter and applause)

Mr. Hastings has demonstrated over many years a gift of oratory in the silver tongue of Virginia, which few of us can ever possess. In the Proceedings, where you find his remarks punctuated with applause, mine will more likely have laughter.

I thank you all for the confidence which has elevated me, however unworthy, to the highest position in your gift, and I hope that I shall not disappoint you. Thank you. (Applause)

I think we ought to see the new Vice-President, Mr. Clarke. Will Mr. Clarke stand and be identified? (Applause)

You know, of course, that Mr. Bond becomes the senior vice-president.

We have three new Directors: Mr. Miller, Mr. Palmer and Mr. Chinn. (Applause)

Is there any further business to come before the Forty-first Annual Convention? The Forty-first Annual Convention stands adjourned.

(The meeting adjourned at four-five o'clock.)

The Outlook for Railroad Legislation

Abstract of an Address Presented Before the Annual Luncheon of the American Railway Engineering Association on March 13, 1940

By R. V. Fletcher

Vice-President and General Counsel, Association of American Railroads

Congress has been in session now for two and one-half months, and the general opinion seems to be that it will conclude the present session about June 1, or perhaps not later than June 15, 1940. Numerous more or less authentic statements have been issued by the Senate and House leadership, outlining the principal legislative measures which the leaders expect to consider. The only bill affecting transportation which is found on all these lists is the so-called Wheeler–Lea bill, commonly known as S. 2009. There is every probability that this bill will be voted upon by the Congress before the session adjourns.

The bill will be known, if it becomes a law, as the Transportation Act of 1940. It was the outgrowth of a report made to the President by a committee of three railroad executives and three railroad labor executives, sometimes popularly referred to as the Committee of Six. That committee, in the fall of 1938, carefully considered the railroad problem in all its phases and made a series of recommendations, some of which are embodied in the instant legislation.

The Board of Directors of the Association of American Railroads, by a majority vote of the members, endorsed the recommendations of the Committee of Six and later instructed the attorneys for the Association to prepare a bill which would embody those recommendations. That bill was introduced into the House by the chairman of the House Committee on Interstate and Foreign Commerce and bears the number H. R. 4862. It should be understood that this bill was never adopted in its entirety by either house of Congress.

The Senate Committee on Interstate Commerce prepared its own bill, and the House committee prepared another bill, approaching the subject from a different point of view. The Senate bill represented a codification of the Interstate Commerce Act in such a way as to apply to all forms of transportation regulating provisions so that the same type of regulation would apply to each form of transportation in so far as they were capable of being uniformly regulated. The House bill, on the other hand, following the recommendation of the Interstate Commerce Commission, contained three parts. Part I dealt with the regulation of the railroads, the pipe lines, the Pullman Company and the express company; Part II dealt with the regulation of the motor carriers and Part III with the regulation of the water carriers.

Bills Being Considered in Conference

The Senate, at the first session of the 76th Congress, in the late spring of 1939, passed the bill reported favorably by the Senate committee, which bill embodied the codifying idea. The House, some weeks later, just before the adjournment of the first session of the 76th Congress, passed the House bill with certain important amendments. In view of the differences between the two bills, it was necessary that they be considered in conference and prior to the adjournment of the first session a conference committee was appointed. These conferees were not able to begin their consideration of the two bills until the meeting of the third session of the Congress, now in session. For some three or four weeks, the conferees have been laboring patiently and diligently to reconcile the differences between the two houses, so that a bill may be reported which will improve not only the railroad situation, but also the transportation situation as a whole. No one can predict with confidence what the conferees will report, although there are some helpful features of the two bills which are likely to be adopted, since the House and Senate have practically agreed upon the significant features of the new legislation.

In the first place, both bills contain a very sound declaration of policy, which commits the Congress to the principle of equality of regulation and which recognizes fully the importance of all forms of transportation. The Senate draft, which differs slightly from the House draft, for the first time in the history of legislation declares a national transportation policy to be applied fairly and in such a way as to recognize and preserve the inherent advantages of each type of transportation. It declares the interest of Congress in safe, adequate, economical and efficient service, to be established and maintained at reasonable rates, without any unjust discriminations or favoritism. The declaration also recognizes the right of employees to have fair wages and equitable working conditions established through collective bargaining, all to the end of insuring the development and preservation of a national transportation service adequate at all times to meet the full needs of commerce. By an amendment inserted by the House, it is declared to be the duty of the regulating authority to administer and enforce its rules with a view to carrying out this declaration of policy. Heretofore, the motor carriers and the water carriers have been declared by Congress to be important and essential and the declaration of policy in the present bill extends this broad statement to include the railroads, as well as their competitors.

The bill measurably improves the present law with respect to consolidations, in that it removes certain obstacles found in the present law, the principal of these obstacles being the requirement that the Interstate Commerce Commission shall formulate and adopt an artificial plan in advance, to which the railroads are required to conform unless they can persuade the commission to modify it. Another of these obstacles relates to the standards which shall govern the Interstate Commerce Commission in passing upon consolidations, these standards being the preservation of competition, the existing channels of trade and commerce and the like. For these difficult and impossible standards, the proposed bill substitutes a single standard, that being the public interest.

The effect, however, of the wholesome changes in legislation so far as consolidations are concerned, would be largely destroyed by an amendment commonly known as the Harrington amendment, inserted in the House bill while it was under debate in the House, which if it remains in the bill will make consolidations impossible. The original bill as reported by the House committee required the Interstate Commerce Commission, as a prerequisite to its approval of any consolidation, to embody fair and equitable arrangements to protect the interests of employees. The so-called Harrington amendment provides, however, "that no transaction shall be approved by the commission if such transaction will result in unemployment or displacement of employees of a carrier or carriers, or in the impairment of existing employment rights of said employees." It is perfectly obvious that if this provision remains in the bill, there can be no motive or incentive to consolidation, however much the public interest might require the practice of economies. Obviously if railroads are consolidated, some unemployment will result and some employees will be displaced and some of the seniority rights of employees will be impaired.

Would Regulate Water Carriers

One principal feature of the bill relates to the regulation of the rates of water carriers. It has long been recognized by every thoughtful student of the question that all forms of transportation engaged in a common competitive field should be subjected to regulation or all should be freed from regulation, so that something like equality of opportunity might prevail. There can be no opportunity for the American people to make a fair test of which form of transportation is best suited to their needs unless the conditions of the race are fair. As the matter stands now, water transportation has been heavily subsidized by liberal grants of public money to enlarge and improve waterways. No tolls are charged for the use of these waterways and no return is received by the government from those who use the waterways commercially for the privilege of using them.

The bill proposes that water carriers hauling goods for the public shall be required to publish their rates if they are common carriers and to file their minimum rates if they are contract carriers. This obviously fair feature of the bill has been endorsed by the President of the United States, by the Interstate Commerce Commission and by a large group of water carriers operating in intercoastal service and on the inland waterways. The regulation of the water lines is opposed, however, by certain water carriers, many of which are under the control of large shippers who find themselves in the happy position of being free to contract, without publicity or regulation, at rates lower than the rail rates, while at the same time the product is sold upon the basis of the rail rates.

It is said by some of those who oppose the regulation of the water lines that the remedy lies not in putting regulation on vessels operating on the Great Lakes, in domestic commerce, intracoastal or intercoastal, and on the inland waterways, but that regulation should be removed from the railroads. However, none of the persons interested in water transport would be willing to repeal the long and short haul clause or to permit the railroads to engage in water transportation or to allow the rails to refuse to join in joint through rates with the water lines. The sincerity of those who argue that the remedy lies in relaxing regulation can be tested by inquiring if they are willing to support a bill which would permit the railroads to make any rate they please to meet water competition.

Another important feature found in the Senate bill but not in the House bill provides for the appointment by the President of a board of three to investigate the question of subsidies and the question of how best various forms of transportation can be integrated in such a way as to make certain that the public is given the privilege of selecting that form of transportation which it finds to be most economical and most suited to its needs. The country is deluged with assertions with reference to the question of subsidies and it is high time that some disinterested, authoritative body be created for the purpose of making an impartial study, in order that this much disputed question may be put to rest. It is obvious that the Interstate Commerce Commission is not the proper body to make this investigation, since it is charged with the duty of regulation, which is inconsistent with the duty of making research and recommendations.

It is not pretended that the enactment of this law will solve the railroad problem, in the sense that it will transform an industry bristling with difficulties into one which is happy and prosperous. Nothing can take the place of a real revival in business. No legislation that can be suggested will supply the needed traffic or restore the railroads to their former prosperity. The railroads have suffered, along with other forms of business, from the general depression which has afflicted the country for more than a decade. They have suffered also from the diversion of immense amounts of traffic to the highways and the water lines, some of which at least have been the beneficiaries of enormous Government subsidies.

No one advocates any sort of legislation which would give the railroads an undue advantage. They are not asking to be subsidized at the hands of a generous government. They are hopeful that if the legislation now pending in Congress is enacted, either in the form of the Senate bill or the House bill, a step will be taken in the process of bringing order into a situation which has been rendered chaotic by reason of the failure to apply the same principle to all agencies of transport. That the situation has been most confusing and unsatisfactory no one denies. The unsatisfactory state of affairs is attributable to changing conditions and to the fact that we are constantly facing new economic problems, resulting from world disturbances and from conditions which have always marked a change from one system to another.

No one believes that the railroads are obsolete or obsolescent. It is easy enough to demonstrate their importance in any well thought-out economic order. The time has passed when they are to be considered as otherwise than useful agencies of transportation, entitled to fair treatment. S. 2009 recognizes them as essential aids to business and it is sincerely hoped that Congress will not adjourn without giving due recognition to the importance of equality, so that privilege, which is a hateful word in every democracy, may no longer be extended to one group of citizens to the detriment of another.

American Railway Engineering Association

REPORT OF THE SECRETARY

March 1, 1940.

To the Members:

This report covers the activities of the American Railway Engineering Association during a year of sharp contrasts. Increased railway earnings have served to stimulate enthusiasm and foster renewed courage, but the many grave problems that confront all industry in a troubled world remain unsolved.

The net effective membership of the Association has changed but little since the last convention. An encouraging increase in the number of applications for membership has been offset by formidable losses, a considerable portion of which may be ascribed to disturbed world conditions. For example, the wars in Europe and in the Far East and unfavorable exchange rates are discouraging membership in foreign countries, and without doubt are responsible for a decline of 25, or 24 percent, in the number of members in countries other than the United States and Canada. The progressive increase in the average age of persons in railway employ is reflected in the growing losses due to death and to the gradual increase in the roll of life members.

However, in spite of these unfavorable influences, the Association has fared remarkably well. With gross revenues for 1939 substantially equal to those for 1938, it was possible to effect an increase of $730.84 in the net revenues, compared with 1938, and to increase the net assets by $2,310.16. The Association's finances are in a thoroughly sound condition, and insure adequate support for a program of expanded activity during the coming year.

Finances

The financial statement, which appears on another page, may be summarized as follows:

	Budget Estimate	Actual
Receipts	$26,300	$28,188.92
Disbursements	26,300	24,276.51
Excess of receipts over disbursements		$ 3,912.41

The receipts for 1939 were $28,188.92, or $233.05 less than in 1938, the decrease being due almost entirely to a decline of nearly that amount in membership accounts. The disbursements for 1939 were less by $963.89 than in 1938, and this decline is to be accounted for primarily by a difference in the outlay for publications. This is due in part to the fact that the expenditures for 1938 included the charges for the December, 1937, bulletin, which, but for late billing, would have been included in the 1937 accounts.

Taking these facts into consideration, it is evident that the operations of the Association during the two years differed very little.

Membership

The table below is a record of the changes in the membership rolls during the year:

Members on rolls as of March 1, 1939			1,920
Additions during the year			102
			2,022
Losses by death	42		
Resigned	27		
Dropped	73		142
Net loss		40	
Membership as of March 1, 1940			1,880

These figures indicate a net loss of 40 members. However, this loss is more apparent than real, because of action of the Board of Direction in advancing the date for the dropping of delinquent members. Thus, on January 1, 1938, the rolls included 32 members two years in arrears for dues, whereas in January, 1939, the membership included none in that category.

It is of interest to note, also, that from June 1, 1939 to March 1, 1940, the number of applicants for membership totaled 81, compared with 53 for the corresponding months a year earlier. That this trend has been uniform is indicated by the fact that the number of applications received in the later period was greater in each month except two.

The Association suffered a severe loss in 1939 through the death of 42 valuable and revered members. Among the deceased members, whose names are listed on following pages, was W. C. Cushing, a past-president (1911–12) and also both a charter member and an honorary member. Others meriting special mention are E. W. Boots (a charter member), A. F. Blaess, Charles Donnelly, Carl Gray, Hans Ibsen, C. W. Johns, R. G. Kenly and J. W. King.

Publications

Bulletins—The publication schedule adopted in December, 1937, under which seven issues are published annually, appears to be entirely adequate. This plan provides two "summer" bulletins, June–July, and September–October, that are available for the publication of monographs. Thus, the material appearing in Bulletin 411, June–July, 1939, included:

Fifth Progress Report of the Joint Investigation of Fissures in Railroad Rails, by H. F. Moore
First Progress Report on Joint Investigation of Continuous Welded Rail, by H. F. Moore, H. R. Thomas and R. E. Cramer
Report on Stresses in Railroad Track, by A. N. Talbot
Preliminary Report of the Committee on Ties, embracing the tie renewal statistics for 1938

The Association was particularly fortunate in receiving for publication in Bulletin 412, September–October, 1939, a monograph on Federal Valuation of Railroads, by Edwin F. Wendt, which comprises an authoritative and comprehensive record of an important phase of American railway history. In addition to the reports of the Electrical Section of the Engineering Division, this bulletin also contained a valuable contribution to the knowledge of structural design in a monograph on Design of Connection Angles for Stringers of Railway Bridges, by W. M. Wilson, based on investigations carried on under his direction at the University of Illinois. This treatise is offered by the Committee on Iron and Steel Structures as the report on one of its assignments.

Bulletins 413 to 416, inclusive, contain the reports of the Association's 27 standing and special committees, the same number as a year ago. The elimination of the Special Committee on Economics of Bridges and Trestles, which was withdrawn by action of the Board of Direction on March 16, 1939, was offset by the restoration of Committee 12—Rules and Organization, after one year of suspended activity. In this connection, it is of interest to note that there was little change in the total number of pages of printed matter, namely, 627 pages for the current reports, compared with 598 a year ago.

Proceedings—Volume 40 (1939) of the Proceedings, containing the committee reports and the discussions thereon at the fortieth annual convention, was completed, ready for distribution, on July 1, 1939, or about three weeks earlier than in 1938. This advance in the date of publication is the result of a consistent effort to expedite the printing and binding of the Proceedings extending over a period of three years, during which the interval between the date of the convention and the date on which the Proceedings were ready for mailing has been shortened by more than two months. In view of the progress already made in this direction, further improvements in the publication schedule will be difficult of attainment.

Manual—The third supplement to the loose-leaf Manual, covering the revisions and additions adopted at the 1939 convention, was ready for distribution on October 1, 1939, or about five weeks earlier than in 1938. The preparation of these Manual supplements is the most exacting task imposed on the secretary's office.

A measure of the relationship between the revisions of and additions to the Manual during the three years since the publication of the loose-leaf volume in 1936 is afforded by the following table:

Supplement	New Sheets Issued	Old Sheets Withdrawn	Net Increase
1937	110	69	41
1938	151	121	30
1939	128	95	33
Total	389	285	104

During the last year 152 copies of the Manual were sold, bringing the total distribution to 1,738.

In addition to complete Manuals, the sale of certain chapters individually has been sufficient to exhaust the stocks set aside for that purpose. For that reason it has been necessary to reprint the chapters on Iron and Steel Structures and on Waterproofing. Other popular chapters now in need of reprinting are those on Rail, Track, Wood Bridges and Trestles, Masonry, and Wood Preservation.

Track Plans—Part 2 of Bulletin 416 consists of 32 trackwork plans, which represent the initial step in a program for the entire revision of the portfolio of plans that is now being carried out by the Committee on Track with the approval of the Board of Direction. As it is proposed to complete the revision of the plans in time for presentation at the convention in 1941, it will be necessary for the committee to submit a further lot of some 160 or more plans to the members during the coming year. For the purpose of simplifying the problem of distribution it is planned to make these available to the members in three installments, namely, with the June–July and September–October bulletins for 1940 and the February bulletin for 1941.

Following approval by the convention this year, the first lot of 32 plans will be made available for sale through the secretary's office, either in sets or individually.

Work of the Committees

A total of 648 members are identified with the Association's 27 committees, but the sum of the memberships of all the committees exceeds this total by 200, because five committees are composed entirely of representatives of other committees and because some men serve on more than one committee. The sizes of individual committees range from 5 for the Special Committee on Complete Roadway and Track Structure to 64 for the Committee on Track. The average is 32.

The work of these 27 committees during the past year is embraced in 627 pages of reports, supplemented by 32 insert sheets, in addition to the 32 trackwork plans. The number of pages occupied by individual reports varies between much wider limits than the sizes of the committees. Thus, one report embraced 115 pages and 20 folded inserts, while two consist of only one page and one of two pages. The median report has a length of 20 pages, while the average of the reports is 23 pages.

Eliminating from consideration 8 committees that have general assignments of a continuing nature, 19 committees were given a total of 175 assignments and presented reports on 111 of them. One committee reported on 12 out of a total of 14 assignments.

Including all the committees, the matter reported was presented in 122 appendixes or topical subdivisions. For the purpose of affording an idea of the types of reports presented, an effort has been made to place them in several classifications or groups, as is indicated in the following paragraphs. The classification is an arbitrary one, which in some cases involved the placing of a report in one group which might perhaps have been placed just as well in some other category.

By far the largest group of reports is that which embraces subjects on which the committees have presented general or specific information, there being 40 of these in all.

Manual material is covered by 27 items, exclusive of recommendations relating to minor revisions. Of these 27 items, 11 comprise new material and 16 represent revisions of material now in the Manual. In addition, 7 reports represent tentative presentations of matter to be offered for adoption later.

Two reports comprise the results of mathematical or analytical studies, 13 others present the results of research investigations, while 13 are essentially of a statistical nature. There are also 2 extensive bibliographies and 18 brief statements of progress.

For the third successive year the reports have been published in accordance with a schedule in which each committee is assigned a specific date on which the report is to be filed with the secretary. This plan has worked so well and has so many advantages that no more than a brief mention of it is warranted. The success of this plan must be ascribed to the excellent cooperation of the chairmen of committees and subcommittees.

Revision of "General Information"

Immediately following the Constitution in this book there appears for the first time a completely revised and rewritten version of the "General Information", comprising General Rules for the Preparation, Publication and Consideration of Committee Reports and Rules for Publication of the Manual. The revision of these rules, which was approved by the Board of Direction, was undertaken for the purpose of bringing them into conformity with practice which has been subjected to a pronounced though gradual change since the original rules were adopted. While a reasonable uniformity of practice has been assured in the absence of up-to-date written rules, by reason of the thorough schooling received by committee members before being advanced to chairman, it is believed that a thorough study of the revised rules will be very helpful in directing the work of the committees along proper channels. Particular attention is directed to the portion of these rules that defines the place of research in committee work and outlines the procedure to be followed in requesting appropriations for research projects.

In carrying on his work for an organization like the AREA, the secretary must keep constantly in mind that, whereas he and the members of his staff are in a position to give their entire time to the affairs of the Association, the efforts of others on behalf of its diversified interests represent a plus service for which they must find opportunity outside the tour of their regular duties. For this reason your secretary is keenly appreciative of the helpful assistance and excellent cooperation he has received from the membership during the last year.

GEOGRAPHICAL DISTRIBUTION OF MEMBERSHIP

United States and Possessions

Alabama	14
Arizona	2
Arkansas	9
California	52
Canal Zone	1
Colorado	22
Connecticut	26
District of Columbia	31
Florida	11
Georgia	25
Hawaii	1
Idaho	1
Illinois	305
Indiana	36
Iowa	19
Kansas	27
Kentucky	31
Louisiana	13
Maine	6
Maryland	34
Massachusetts	42
Michigan	45
Minnesota	61
Mississippi	6
Missouri	98
Montana	6
Nebraska	22
New Hampshire	5
New Jersey	34
New Mexico	1
New York	149
North Carolina	14
Ohio	145
Oklahoma	8
Oregon	7
Pennsylvania	147
Puerto Rico	1
Rhode Island	2
South Carolina	2
South Dakota	2
Tennessee	22
Texas	68
Utah	5
Vermont	7
Virginia	87
Washington	15
West Virginia	20
Wisconsin	12
Wyoming	2
	1701

Other Countries

Canada	100
Mexico	12
Australia	9
Brazil	9
England	7
Argentine	6
Central America	5
China	4
Japan	4
Cuba	4
India	3
Manchukuo	3
Un. Soc. Sov. Rep.	2
Czechoslovakia	2
Bolivia	1
Colombia	1
France	1
Germany	1
Peru	1
Poland	1
Sudan	1
Switzerland	1
Tanganyika Territory	1
	179

Deceased Members

A. B. ARGANBRIGHT
Superintendent Inspection and Tests, Wheeling Steel Corporation, Portsmouth, Ohio.

M. M. BACKUS
Assistant Chief Engineer Maintenance of Way, Illinois Central System, Chicago.

A. F. BLAESS
Chief Engineer (Retired), Illinois Central System, Chicago.

R. G. BOAST
Division Engineer, Temiskaming & Northern Ontario Railway Commission, Engelhart, Ont.

E. W. BOOTS
Consulting Engineer, 319 South Fairmount Street, Pittsburgh, Pa.

C. W. COCHRAN
Examiner in Charge, Philadelphia District, Bureau of Valuation, Interstate Commerce Commission, Philadelphia, Pa.

W. C. CUSHING
Engineer Standards (Retired), Pennsylvania Railroad, Philadelphia, Pa.

W. O. DENNIS
Engineer Maintenance of Way, Lehigh & New England Railroad, Bethlehem, Pa.

CHARLES DONNELLY
President, Northern Pacific Railway, St. Paul, Minn.

C. W. EBY
Assistant Engineer, Waterloo, Cedar Falls & Northern Railway, Waterloo, Iowa.

P. D. FITZPATRICK
General Manager, Grand Trunk Western Railroad, Detroit, Mich.

R. C. GOWDY
Chief Engineer, Colorado & Southern Railway, Denver, Colo.

C. R. GRAY
Vice-Chairman, Board of Directors, Union Pacific System, New York.

T. B. HAMILTON
Vice-President (Retired), Pennsylvania Railroad, Culver, Ind.

C. J. HARRINGTON
Division Engineer, Illinois Central Railroad, Champaign, Ill.

H. M. HOCKMAN
Division Engineer, New York, Chicago & St. Louis Railroad, Frankfort, Ind.

H. L. HUNTER
Office Engineer, Atchison, Topeka & Santa Fe Railway, Topeka, Kans.

HANS IBSEN
Consulting Engineer (Retired), Michigan Central Railroad, Detroit, Mich.

R. G. KENLY
Chief Engineer (Retired), Minneapolis & St. Louis Railroad, Minneapolis, Minn.

C. W. JOHNS
Chief Engineer, Chesapeake & Ohio Railway, Richmond, Va.

J. W. KING
Vice-President, Operations and Maintenance Department, Association of American Railroads, Washington, D.C.

Deceased Members

W. S. KING
General Tie and Timber Agent, Chesapeake & Ohio Railway, Cleveland, Ohio.

J. E. KISSELL
Division Engineer, Cleveland, Cincinnati, Chicago & St. Louis Railway, Bellefontaine, Ohio.

P. G. LANG, JR.
Engineer of Bridges, Baltimore & Ohio Railroad, Baltimore, Md.

O. F. MCNAIRY
Assistant Division Engineer, Seaboard Air Line Railway, Jacksonville, Fla.

GRANT MONK
Chief Inspector of Gary Works, Carnegie–Illinois Steel Corporation, Gary, Ind.

J. T. MORRISON
President, Pullman Railroad Company, Chicago.

P. C. NEWBEGIN
Chief Engineer, Bangor & Aroostook Railroad, Houlton, Me.

A. G. NORTON
Contracting Engineer and Architect, Middletown, N. Y.

HAROLD A. OSGOOD
Vice-President, Fulton Iron Works, St. Louis, Mo.

J. N. OSTROM
Consulting Bridge Engineer, Chicago, Burlington & Quincy Railroad, Chicago.

GUY PINNER
Chief Engineer, American Cyanamid Company, New York

J. G. REID
Assistant Superintendent, Canadian Pacific Railway, Prince Albert, Sask.

PRA SATHIEN
Division Engineer, Siamese State Railway, Bangkok, Siam.

B. B. SHAW
Manager, Georgia Kaolin Company, Dry Branch, Ga.

T. J. SKILLMAN
Chief Engineer Consultant, Pennsylvania Railroad, Philadelphia, Pa.

J. A. SOMERVILLE
Vice-President, Texas & Pacific Railway, Dallas, Texas.

S. SUGIURA
Vice-President, Tokyo Gas Company, Ltd., Tokyo, Japan.

H. M. SWOPE
Division Engineer, Atchison, Topeka & Santa Fe Railway, Emporia, Kansas.

R. T. TAYLOR
Superintendent, Northern Pacific Railway, Tacoma, Wash.

W. J. WATSON
Consulting Engineer, Cleveland, Ohio.

GEO. H. WELLS
3434 Whitefield Avenue, Cincinnati, Ohio.

FINANCIAL STATEMENT FOR CALENDAR YEAR ENDING DECEMBER 31, 1939

Balance on hand January 1, 1939		$81,410.85

RECEIPTS

Membership Account	
Entrance Fees	$ 937.00
Dues	17,478.75
Binding Proceedings	1,470.93
Sales of Publications	
Proceedings	1,083.94
Bulletins	1,449.25
Manuals	1,668.47
Specifications	866.70
Track Plans	277.43
Advertising	
Publications	777.89
Interest Account	
Investments	2,098.06
Miscellaneous	80.50
Total	$28,188.92

DISBURSEMENTS

Salaries	$ 8,250.11	
Proceedings	3,793.13	
Bulletins	3,858.36	
Stationery and Printing	706.92	
Rents, Light, etc.	780.00	
Supplies	61.15	
Expressage	26.20	
Postage	472.71	
Exchange	82.64	
Committee Expense	140.02	
Annual Convention	776.26	
Refunds, dues, etc.	57.80	
Audit (year 1938)	200.00	
Pensions (E. H. Fritch—A. K. Shurtleff)	2,460.00	
Social Security Act	77.47	
Manual Supplements	904.55	
Track Plans	877.70	
Miscellaneous	156.41	
Joint Bar Investigation	430.41	
Equipment	157.72	
Accrued Interest, etc., on Bonds Purchased	6.95	
Total	$24,276.51	
Excess of Receipts over Disbursements		3,912.41
Balance on hand December 31, 1939		$85,323.26

REPORT OF THE TREASURER

To the Members:

Balance on hand January 1, 1939		$81,410.85
Receipts during 1939	$28,188.92	
Paid out on Audited Vouchers, 1939	24,276.51	
Excess of Receipts over Disbursements		3,912.41
Balance on hand December 31, 1939		$85,323.26
Consisting of		
*Bonds at cost	$75,945.81	
Cash in Northern Trust Company Bank	9,116.79	
Cash in Royal Bank of Canada	235.66	
Petty Cash	25.00	
	$85,323.26	

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* Includes $6,240.00 book value of Rock Island, Arkansas & Louisiana 4¼% bonds due March 1, 1934, not paid, in default.

Also includes St.L.S.W. 5% bonds, book value $1,319.31, interest coupons January 1, 1936 and thereafter in default.

Respectfully submitted,

W. H. Penfield, *Treasurer.*

We have made an audit of the accounts of the American Railway Engineering Association for the year ending December 31, 1939, and find them to be in accordance with the foregoing statements.

(Signed) E. Deming,
C. G. Rivers,
Auditors.

GENERAL BALANCE SHEET

December 31, 1939

Assets	1939	1938
Due from Members	$ 765.00	$ 1,467.50
Due from Sales of Publications	25.95	38.15
Due from Advertising	56.00	50.00
Furniture and Fixtures	410.00	300.00
Publications on hand (estimated)	2,000.00	2,000.00
*Investments (cost)	75,945.81	74,939.56
Interest on Investments (accrued)	607.29	641.25
Cash in Northern Trust Company Bank	9,116.79	5,725.13
Cash in Royal Bank of Canada	235.66	721.16
Petty Cash	25.00	25.00
Manuals (on hand)	2,800.00	4,200.00
Joint Bar Investigation (Due from A.A.R.)	430.41	......
Total	$92,417.91	$90,107.75
Liabilities		
Members' Dues Paid in Advance	$ 5,153.75	$ 5,194.00
Surplus	87,264.16	84,913.75
Total	$92,417.91	$90,107.75

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* Includes $6,240.00 book value of Rock Island, Arkansas & Louisiana 4¼% bonds due March 1, 1934, not paid, in default.

Also includes St.L.S.W. 5% bonds, book value $1,319.31, interest coupons January 1, 1936 and thereafter in default.

Dominion of Canada 3% bond due June 1, 1955, par value $1,000 purchased during year 1939 for $1,006.25.

Discussion on Signals and Interlocking

(For Report, see pp. 38–42)

(President Hastings presiding)

Chairman H. G. Morgan (Illinois Central): The report of the Committee on Signals and Interlocking is purely informative. The principal item is that of development in railway signaling. A report is presented on the use of coded track circuits. Since this report was written there have been further developments in the use of coded track circuits and further extensions in their use. Mr. Post, the chairman of the subcommittee, will have something further to say to you.

Mr. W. M. Post (Pennsylvania): Our first report appears on page 38, "Development in Railway Signaling." The new development is the use of coded track circuits 11,000 ft. long. The practicable limit for track circuits has been from 5,000 to 6,000 ft. By means of refinements in track circuit devices and improved track bonding, it is now practicable to extend their length to fit in with the longer spacing between automatic signals. Due to higher speeds and heavier trains, the trend in recent years has been to increase the distance between automatic signals from one mile to two miles. Heretofore it has been necessary to provide two track circuits for each of the longer automatic blocks. The use of different code frequencies has made it possible to eliminate line wires. Two signal indications were all that could be transmitted over the track circuit until the coded track circuit was developed. By coded track circuit is meant a track circuit current interrupted a predetermined number of times per minute, that is, 75 times for an approach signal, 120 times for an approach medium and 180 times for a clear signal.

The absence of coded current or the presence of non-coded current in the track circuit causes the most restrictive signal—Stop, or Stop and Proceed—to be displayed. Additional signal indications can be provided by the use of equipment to provide additional code frequencies if and when necessary.

Since the preparation of this report there has been quite an extension of the use of 11,000-ft. track circuits. There is now under construction a 100-mile stretch of double-track signaling, in which the 11,000-ft. track circuit is being used, and it is under contemplation at other points. It is beyond the experimental stage, it is practicable, it is working, it is economical and it is efficient.

The report on our second assignment, "The Principal Current Activities of the Signal Section," is found in Appendix B on page 39. Your attention is called to the first paragraph stating that there are now available 22 of a series of 24 pamphlets on railway signaling for the education of those desiring to study this subject. A well-informed railroad man should know something about signaling. I believe that these pamphlets offer the best and the most up-to-date matter which can be used for the education of those who desire to know more about signaling.

Referring to the numbered items of the reports under the heading of "Current Activities of the Signal Section," I would like to call attention to No. 1: Costs involved in stopping trains. The Committee on Economics of Railway Signaling has published 26 curves showing the horsepower-hours of work delivered at the axle that are wasted in making stops. These curves represent gross weights of trains and show horsepower-hours of work wasted in making freight train stops from speeds up to 60 miles per hour. Formulas were developed so that this information can be used, together with the cost of fuel and water, the steam factor of locomotive, B.t.u. per lb. of coal and grate area, to determine the cost of fuel and water wasted in making a stop. An example is given for a freight train of 6,450 tons gross weight, 80-ton cars, stopped from 45 m.p.h. and standing six minutes. The answer was that the total cost of fuel and water wasted on account of the stop was $2.37.

I call attention to No. 5, which is another report of this committee on the economic value of battery lighted switch lamps. This report contains information from several railroads using battery lighted switch lamps showing that the savings in operation and maintenance gives an annual return, over and above a 5 percent interest charge on the total cost, varying from 5.7 percent to 29.9 percent.

No. 6 is a report by the Committee on Interlocking describing a slide protection fence, with several plans showing details of such a fence.

Our report on pages 40, 41 and 42 is merely a list of the Revised and New Requisites, Specifications and Drawings, with the old and new numbers and can be found in our Signal literature.

Chairman Morgan: Mr. President, this concludes the report.

President Hastings: Gentlemen, you have heard the report of the Committee on Signals and Interlocking. It is presented as information in order to keep the Association abreast of the developments in signaling and interlocking. Is there any discussion?

The committee is excused with the thanks of the Association. (Applause)

Discussion on Standardization

(For Report, see pp. 25–34)

(President Hastings presiding)

Chairman F. L. Nicholson (Norfolk Southern): In presenting this report, which is largely informative and of a recommendatory nature (nothing being offered for adoption), I desire to call your attention to the personnel of this committee as a means of giving weight to what I shall say.

This committee is composed of the chairmen of all of the standing and special committees. Any subjects that are to be considered are referred to the chairmen of these committees, acted upon by the committees, and then introduced in the report. The subjects that are assigned for consideration are very definite, and we have to adhere strictly to them.

The first subject is "What AREA recommended practices should be advocated for general use on railroads?" The procedure that I have outlined was followed in the preparation of this report. Your committee has reviewed the Manual and submits in Appendix A, a tabulation of recommended practices thought worthy of general use by the railroads in the interest of uniformity in practice, economy and efficiency. A similar tabulation was submitted in 1937, but it was thought desirable to bring this up to date and direct your attention to it again. Your committee earnestly recommends that, in so far as possible, the recommended practices adopted by this Association and approved by the Association of American Railroads be used in your work.

The second subject is: "What AREA recommended practices should be sponsored as subjects for National Standardization?" There are, of course, many subjects that we could adopt for the use of the railroads of the country that would not be useful for general adoption as national standards. We have no subjects to recommend at this time although two or three subjects have been suggested. They are under consideration.

The third subject is: "Maintain contact with standardization bodies and keep the Association informed on important matters developed by such contact." Your committee presents herewith, first, a list of representatives of the Association of American Railroads and of this Association on the council of the American Standards Association and on its Correlating and Advisory Committee. If you will read this, you will find that this Association is exerting an influence on many of the standards now being adopted nationally. Second, we present a list of technical projects on which the AAR is now cooperating with the ASA, together with the names of members representing the AAR in the consideration of such projects. This information was secured first-hand from Dr. P. G. Agnew, secretary of the American Standards Association and is shown in Appendix B.

The report also includes a summary of the activities of the Canadian Engineering Standards Association for the year ending March 31, 1939, the date of the latest information available. This was furnished by Mr. W. R. McCaffrey, secretary of the Canadian Engineering Standards Association and is shown in Appendix C.

A list of the collaborating representatives of the AREA on committees of the American Society for Testing Materials is given as Appendix D.

We hope this information will be serviceable to you and of some value. This completes our report.

President Hastings: Mr. Nicholson, we thank you very much for bringing in another excellent report. As this report is for the information of the Association only, no action is necessary upon it. We commend it to your earnest consideration. The committee is excused with the thanks of the Association. (Applause)

Discussion on Electricity

(For Report, see pp. 35–37)

(President Hastings presiding)

Chairman H. F. Brown (New York, New Haven & Hartford): The assignment of the Committee on Electricity this year as in previous years, is to report to the Association the developments in the application of electricity to railway service and to report on the current activities of the Electrical Section of the Engineering Division.

While there have been no spectacular or outstanding developments in the application of electricity to railway service since the last report of this committee, each year sees refinements of the achievements of previous years and the more extended use of newly developed apparatus and methods. We need not dwell on the business or economic conditions which have existed during the past ten years—conditions which have vitally affected the railroads of this country. It is sufficient to say that, in spite of these conditions which have been some of the most difficult the railroads have had to face in their whole history, the Electrical Section has continued to function and has made important progress, and the application of electricity to railways has also been greatly extended.

The carriers having electrified lines are finding additional advantages and increased flexibility in operation with electric motive power, particularly on lines that handle dense freight traffic. No notable extensions to electrified track or new purchases of electric motive power have been placed in service during the past 12 months.

One of the outstanding achievements of the past two years is the development in new means of illumination, especially in the application of the fluorescent lamp mentioned for the first time in last year's report. This lamp has particular application to railway cars because of its high efficiency, as it is nearly three times as efficient as the best incandescent light used heretofore. This means an important saving in battery and other forms of power supply which must be carried by railway cars.

Electric air-conditioning equipment has been improved and its use extended, both on cars and for terminal servicing equipment. Much of this air-conditioning equipment is electrical. One carrier has developed a portable substation for temporarily servicing parked Pullman cars when normal facilities are overtaxed, for example, during large conventions in the summertime.

Continued improvement has been made in the design of electrically-operated shop tools, welding equipment and electrically-operated roadway maintenance tools, and their use has been extended.

It seems logical to assume that with the development and growth of such large power projects as Boulder Dam, Grand Coulee and others, and the steady growth in power transmission networks, the railroads will share with industrial and rural users the more extended use of electric power for their various requirements.

In 1925 the United States used probably one-half of all the electric power produced in the world. Today it is using about one-third because of the greater advance that some of the foreign countries have made in catching up with American development. There is a large potential field for further use in electric power by the railroads. Leaving aside such important uses as communication and signaling, I think you will all agree that the railroads will realize increased economies and greater ability to give service, with the further adoption and use of electricity in all phases of their operations.

It is encouraging to those who, as engineers, are constantly endeavoring to apply scientific principles to the needs of our every-day life and to public service that progress in science continues in spite of business depression. As we look back over the past ten years, we see many marks of progress in the railroad field. Mr. Buford has already referred to them this morning. Among the most outstanding are the improvements in electric drying equipment, electric illumination, Diesel-electric power and air-conditioning. I believe we have advanced at a greater rate in the last ten years than during any other decade in the history of the railroads.

This year, incidentally, marks the tenth anniversary of the formation of the Electrical Section which grew out of the Committee on Electricity of this Association, and it is fitting to mark this mile-post at this particular meeting.

The activities of the Electrical Section have been summarized in the report. They include power supply, electrolysis, design of overhead transmission line and catenary construction, standardization of apparatus and material, electric heating and welding, the application of motors, clearances for third-rail and overhead working conductors, protective devices and safety rules in electrified territory, specifications for track and third-rail bonds, illumination, design of outdoor and indoor substations, high tension cables, and the application of corrosion resisting materials to railroad electrical construction.

In addition to these, a great deal has been done this past year in the preparation of additional material for inclusion in the Electrical Section's Manual. While not specifically covered in the report of the Electrical Section this year, mention should be made of the special committee for coordinating the work of the various sections of the AAR interested in electrical and allied matters, which should be instrumental in assuring unanimity of opinion and in avoiding overlapping and duplication of effort in the work of the various sections in these matters.

It would not be fitting for me to close this report without again mentioning the very great help that I have had from your president and his predecessors in connection with matters pertaining to the Electrical Section. I wish to also express my appreciation to all those who have taken part in the committee work, all of which, as on other committees, is entirely voluntary and does take a lot of valuable time.

President Hastings: Thank you, Mr. Brown.

This is another of the reports presented to us for the information of the membership. It has been a real pleasure for me to deal with Mr. Brown in his work as Chairman of the Electrical Section of the Engineering Division, and I know that in his hands the work of the Electrical Section is going to move forward in the days ahead. Is there any discussion of this report?

Mr. W. A. Radspinner (Chesapeake & Ohio): I would like to ask the chairman whether any of the railroads have used the infra-red rays in the application of paint to their cars.

Chairman Brown: That is mentioned in the report of the Committee on Illumination. For your information, I will cite the paragraph in connection with that.

> "There has been developed at commercial voltages a 250-watt lamp, the chief function of which is to produce near infra-red radiation for heating purposes, the low quantity of visible radiation being secondary and more or less incidental. The equipment required to generate and control the near infra-red radiation is markedly similar to that used in the case of light or visible rays. The lamp is designed to provide a proper balance between the radiations which are absorbed and those which are transmitted by the more common lacquers which it is designed to dry. The filaments operate at relatively low temperature so the light of these lamps is very low. This source of heat is found to accelerate certain drying processes very materially.
>
> "For instance, one large automobile company is able to dry a finished car body in 7 min. whereas the shortest time required by other available means is 30 min."

In answer to your direct question, I am not sure whether this has been applied to any of our car shops but the information is presented by the committee to call to the attention of the railroad users the existence of these new electrical tools as they are developed.

President Hastings: Are there any other questions? If not, the committee is excused with the thanks of the Association. (Applause)

Discussion on Complete Roadway and Track Structure

(For Report, see pp. 639–645)

(Vice-President Bond presiding)

Chairman John E. Armstrong (Canadian Pacific): I would like to warn you in advance that we are presenting reports on both of the subjects assigned to this committee, and, if the convention approves the recommendations, the committee will have completed its assignments and will no longer be required.

The first subject is that on Classification of Railways. This committee submitted to last year's convention a tentative classification of railway main tracks for discussion, criticisms and suggestions. The discussion, criticisms and suggestions received indicate that, in general, the tentative classification was acceptable but that it did not make entirely clear just what was intended. The ambiguous matter has been clarified.

I shall now present the Traffic Classification of Railway Main Tracks which your committee recommends be adopted for publication in the Manual. It is not long, and it may be well for me to read the proposed Manual material.

(Chairman Armstrong read the material appearing under "Traffic Classification of Railway Main Tracks" appearing on pages 639–640, down to and including the note.)

Chairman Armstrong: It is the view of your committee that, with the changes presented in the classification statements, together with the note, which is a part of the material proposed for the Manual, all ambiguity has been removed from these classification statements.

I move that this traffic classification of railway main tracks and the note pertaining thereto be adopted for inclusion in the Manual.

(The motion was seconded, put to a vote and carried.)

Chairman Armstrong: That carries us on to the second assignment to this committee which is Complete roadway and track structure for various loads and traffic densities, the report on which appears as Appendix B, page 640.

This committee submitted to last year's convention a tentative schedule of classes of complete roadway and track structure under AREA Recommended Practice, for discussion, criticisms and suggestions. All discussions, criticisms and suggestions received have been considered.

In conjunction and conformity with the traffic classification of railway main tracks which, by your action, you have just approved, we now present a schedule of classes of complete roadway and track structure under AREA recommended practice as of 1939. This schedule appears on pages 642 to 645, inclusive. Your committee recommends that this report be accepted as information and that, immediately after the traffic classification of railway main tracks, as it will be printed in the Manual, there be printed a reference as follows:

(Chairman Armstrong read the material appearing under "Schedule of Classes of Complete Roadway and Track Structure—1939", directing attention to a change in the reference "on pages 642 to 645" to "on pages 640 to 645". His moton for the inclusion in the Manual of the reference to the schedule was seconded, put to a vote and carried.)

Chairman Armstrong: This completes the report of this committee and, as far as your commitee is aware, completes the work of this special committee.

Vice-President Bond: The Special committee has been at work on this assignment for a number of years and now comes to us with definite and specific recommendations which you have accepted. The committee is excused with the thanks of the Association. I take note of the fact that the committee has asked to be discharged, but I think that is rather the function of the Committee on Outline of Work. We have the privilege of thanking you very much for what you have done and trust that the Committee on Outline of Work will take cognizance of your request. (Applause)

Discussion on Uniform General Contract Forms

(For Report, see pp. 43–56)

(President Hastings presiding)

Chairman W. G. Nusz (Illinois Central): The first subject assigned to the committee was, Revision of the Manual. All of the uniform general contract forms were very carefully reviewed prior to the publication of the present Manual. They have been again reviewed carefully during this year and we have no revisions to recommend at this time.

The second subject is, Form of agreement to cover operation of commissary and boarding outfits. Last year the committee presented to the convention a tentative form of this agreement. A few suggestions have been received and carefully considered, and the form now presented is recommended for adoption by the Association for printing in the Manual. The report will be presented by the subcommittee chairman, Mr. Swatosh.

Mr. W. R. Swatosh (Erie): The report of Subcommittee 2 will be found in Appendix A. A tentative form of this agreement has been before the Association as information for the past year. The agreement as now printed has been entirely revamped to conform with the suggestions received. The committee is asking approval of the Association for its printing in the Manual. I will read the paragraphs by headings.

(Mr. Swatosh then read paragraph headings 1 to 23.)

Mr. Swatosh: I move the adoption of Appendix A for approval and printing in the Manual.

(The motion was seconded, put to a vote and carried.)

Chairman Nusz: The third subject assigned to Committee 20 was, Form of agreement for commercial signs on railway property. The committee has collected a number of contracts of this character and has prepared a form of agreement under Appendix B, page 48, which is submitted at this time as information and with the request that we receive criticisms and suggestions relative to the form which will later be presented for adoption.

President Hastings: You have heard the statement of the chairman that this form is submitted as information. The committee desires your comments on this agreement. I think I may say that such comments should be in writing so that the committee may make a final revision of this form during the coming year, looking to its presentation next year for adoption. Is that a correct statement, Mr. Nusz?

Chairman Nusz: That is correct.

President Hastings: Is there any discussion at this time? Proceed, Mr. Nusz.

Chairman Nusz: The fourth subject assigned was, Form of lease for air-right development. The committee has collected a number of agreements and a large amount of information covering this assignment. Considerable progress has been made but no form of agreement is presented at this time. It is expected to make a definite recommendation to the Association next year, and the committee requests that the subject be continued.

The fifth assignment was, Form of agreement for electrified fence along right-of-way, which was a new assignment. Information has been collected on the subject, and some progress has been made. However, it appears that there is no particular need at this time for a contract of this kind, and it is recommended that the subject be discontinued.

The sixth subject, Form of blanket agreement for wire line crossings, will be presented by Mr. Nicholson, chairman of the subcommittee.

Mr. F. L. Nicholson (Norfolk Southern): This subject, "Form of Agreement For Wire Line or Cable Crossings" is one that was assigned to a special committee by the Association of American Railroads through our then President, Mr. Morrow. The committee consisted of five representatives of the Construction and Maintenance Section, five representatives of the Electrical Section and one of the Telegraph and Telephone Section. The orders were "to prepare a uniform contract and specifications governing wire crossings as a basis of meeting the requirements of the Rural Electrification Administration which will be satisfactory to the railroads generally."

Before we got through with it, we came to the conclusion that we had a pretty big assignment. The committee went into the matter rather thoroughly and discussed it with the Rural Electrification Administration. We found that their ideas were entirely opposed to ours. They had the idea that they could occupy railroad property in any way, manner or form without any payment for its use. They did not want to give us any liability clauses or any protection against what we considered irresponsible organizations being formed all over the country, known as mutual electric companies.

Several meetings were held, and the committee finally drafted a form that apparently satisfied the Administration, with the exception of the insurance clause and the rate of charges for the service.

The time came for the filing of the report of your committee for printing in the bulletin last October, and we filed for that purpose the form as it had progressed at that time, and we hoped that when it reached the members of this organization they would read it and form some conclusions. However, we continued the contacts with the Rural Electrification Administration, trying to reconcile differences.

We have at last prepared a form that is somewhat different, but not materially, from that published in the bulletin. What has been done is really nothing more than editing of the form that appeared in the bulletin, in other words, there has been some change in phraseology to meet the views of three or four groups of attorneys, including the attorneys of the Administration, and so on. The new form does not change the intent or the meaning of the original contract form.

The committee thought it was necessary to insert the insurance clause because these mutual organizations have little or no financial backing. They are borrowing money from the Rural Electrification Administration, and in the case of accident or a failure that would cause injury to the railroad companies, we would have no one to fall back on to collect for damages under the liability clause.

It was understood by the committee that the REA had no real objection to the insurance clause if the required protection could be secured at a reasonable rate. The REA committee feared that contractual liability insurance would cause considerable expense to the mutual organizations which were represented to be very poor and unable to pay. That clause has been changed slightly in wording to meet the usual clause in the insurance policies covering such protection.

The committee also prepared an information form to be submitted by these organizations to the railroad so as to determine the type of construction and the risk involved, which form must be approved by the railroad before anything is done. That form does not preclude the preparation of proper drawings or plans for actual construction. It is simply an application form to insure uniformity, which the Administration agreed was desirable.

The schedule of fees and rentals which the committee submitted, was considered rather high by the REA as they wanted the service, as I have stated, free of cost. This schedule is now used by the railroads in the eastern and northeastern section of this country in their dealings with power companies and others desiring like service. The position taken by the committee was that we could not agree to any standard contract form, that did not make somewhat similar charges. The committee concedes that this schedule of charges is probably too high for some sections of the country, but feels that it is entirely proper for sections of high property values, or where there is railroad electrification or automatic signaling. At the same time, the committee feels that it is important to establish a principle rather than to determine the exact price to be paid. The committee adopted this schedule for the purpose of submitting to you what might be termed a maximum charge and, where conditions justify, it should be adhered to. The main purpose is to get some uniformity in practice throughout the country and relieve the engineers, having to do with these matters, of the difficulties they are encountering in getting contracts signed for wire line crossings for the Administration. It has become known that the Administration, at least in some cases, has been seeking free service, and it is possible that others are holding back to see what the outcome might be.

The Administration representatives have been advised that, in the judgment of the committee, there should be no free service, although there might be a difference as to what is the fair rate. Perhaps the rates proposed may be too high in some instances and proper in others, but these matters can be adjusted by the railroads themselves to suit the conditions.

After several meetings and correspondence we prepared this final agreement, and it was submitted to the General Committee of the Engineering Division and has already received approval of the majority of the members of that committee. We now feel that our committee has finished its work. We thought first it might be well to ask for a letter-ballot of the member roads, but it is now thought that the best way to dispose of the matter is to submit it to this organization for approval, and thus follow the routine procedure for adoption as recommended practice.

The first contract form which we submitted was offered as information. This final form, as I have stated, has been altered only to the extent of minor editing and certain changes to meet legal requirements. Nothing has been done that affects its intent or meaning. In fact, there was a question in our minds as to whether the editing improved it, but it did not hurt it.

We bring this final form of agreement, application form and schedule of charges before you with this statement and ask you to take such action as you think proper. Our committee thinks it is the last thing we can do. You must recognize that it is absolutely impossible to get all the railroads to agree to all of the provisions, or to get the Rural Electrification Administration to agree to all of it. Much of it, they have agreed to. The only provisions they have officially taken objection to are the insurance clause and the schedule of charges. The committee feels that the important objectives are to establish protection and insure that the railroad will get a return for the use of its property. We believe that each railroad, if it accepts these principles, can fix a rate that will be satisfactory but, by all means, it should fix a rate.

President Hastings: Mr. Nicholson, you have given a very complete exposition of what has taken place with reference to this matter. The Chair understands that you place this question squarely before the convention at this time to express its wishes as to how the matter should be handled.

Mr. Nicholson: Yes, sir.

President Hastings: Is there discussion?

Mr. Geo. S. Fanning (Erie): As this stands now, the special committee has completed its work, the Engineering Division has voted favorably on it, and it seems to me that there is no reason for adopting the suggestion that this be submitted as information. There is nothing more that can be done by this convention or this Association to change it. On the other hand, the statement is made at the end of the introduction that these forms are submitted with the request that the members of the Association bring them to the attention of the proper officer of their managements, with the recommendation that they either be adopted as prepared, or that the principles represented therein be adopted and used in any agreements they prepare.

It seems to me, if we want to handle this for the railroads to use to the best advantage, we had better put it in the Manual where they can use it with all the authority of this Association.

I therefore move, Mr. President, that the Form of Agreement For Wire Line or Cable Crossings as finally amended by the special committee be adopted for inclusion in the Manual.

(The motion was seconded.)

President Hastings: The procedure is a little unusual. However, the need for action is, I think, very evident to all of you. I want to say that the Chair feels that it is an action that should be taken. Therefore, I open it for further discussion. Is there any further discussion?

(Mr. Fanning's motion was then put to a vote and carried.)

President Hastings: I think the convention has taken very wise action in this matter. Thank you very much, Mr. Nicholson, for the splendid work which you and your special committee have done.

Mr. Nicholson: The committee is very appreciative of your action. We have labored pretty hard in the preparation of this report, and we are glad to get a little recognition. (Laughter)

Chairman Nusz: Mr. President, this completes the report of Committee 20.

President Hastings: Committee 20 is another of those committees—not to say that all of our committees are not in that same class—that always brings to us a report that is tremendously helpful. You only need to look back into the volumes of the Association and there you will find the lasting work of Committee 20. Members of the committee ought to be proud of their service to the Association and, certainly, the Association is proud of them. The committee is excused with the thanks of the Association. (Applause)

(The form of agreement, together with Exhibit A—Data to Be Incorporated on Plans, and Exhibit B—Schedule of Fees and Rentals, as revised by the committee following its publication in bulletin form and adopted by the Association on the motion offered by Vice-President Fanning is presented below.)

FORM OF AGREEMENT FOR WIRE OR CABLE LINE CROSSINGS

THIS AGREEMENT, made this .... day of .... 19...., by and between the .... (Railway Company) ...., a corporation duly organized and existing under the laws of ...., hereinafter called the Railway Company, and ...., hereinafter called the Licensee.

WITNESSETH:

WHEREAS, the Licensee desires to construct, maintain and use wire or cable lines and appurtenances, hereinafter called construction, for transmission of electric energy over or under and across the property, tracks and wires of the Railway Company, and over or under and across such wires of any other party or parties as Railway Company has permitted to be placed upon its property, such construction to be located and placed as shown on plan and elevation on the approved drawings, EXHIBIT "A" hereto attached and made a part hereof.

It is mutually agreed as follows:

1. Permit

The Railway Company hereby permits the Licensee to construct, maintain and use said construction over or under and across the property, tracks and wires of the Railway Company, and the wires of such other party or parties as Railway Company has permitted, or may permit, to place wires on its property, but not parallel to the Railway Company's tracks and wires, at such location, plan and elevation as indicated on said approved drawings and subject to the requirements of the Railway Company.

2. Specifications

(a) The Licensee shall install and maintain, at its sole expense, said construction under the supervision and direction and to the satisfaction of the .... of the Railway Company, or his authorized representative and, except in cases of emergency, shall do no work with reference to the construction, reconstruction or maintenance of said construction on the Railway Company's premises, except under such supervision and direction, and after reasonable notice given in writing to the .... of the Railway Company.

(b) The Licensee shall reimburse the Railway Company for any and all expense that may be incurred by the Railway Company in connection with said construction.

(c) Said construction and maintenance thereon shall accord with the latest requirements of "Specifications for Electric Light, Power Supply and Trolley Wires Crossing Railways", as from time to time approved by the Association of American Railroads and printed in the Manual of its Electrical Section, Engineering Division.

(d) If, in any particular, said specifications conflict with the laws of any State having jurisdiction, then said specifications shall be modified only to the extent necessary to meet the requirements of the State law, and in all remaining particulars said specifications shall govern.

3. Use

The Licensee shall use the said construction solely for the purpose of conveying electric energy at a potential not in excess of that shown in each case on said approved drawings, and shall make no change without first securing the approval of the .... of the Railway Company.

4. Protection of Existing Circuits

The Licensee shall protect the telegraph, telephone, signal and other circuits on, over, or under the property of the Railway Company from electrical or other interference or damage by or because of the construction, maintenance and use of said construction, and shall construct, maintain and use said construction in such a manner as will not damage or injuriously affect the use of telegraph, telephone, signal or other circuits of the Railway Company or of other Companies that may now or hereafter have the right to maintain such circuits on the property of the Railway Company.

5. Liability and Risk

(a) The Licensee shall not in any way or at any time interfere with the safe passage of the Railway Company's trains or with the proper and safe use, operation and enjoyment by the Railway Company of its property; and shall indemnify and save harmless the Railway Company and other Companies having facilities on its property from any and all loss or damage to property and injury to or death of any or all persons, or any suits, claims, liability or demands in connection therewith, however caused, resulting, directly or indirectly, by reason of the installation, maintenance, use, existence or removal of said construction, unless due to the sole negligence of the Railway Company.

(b) The Licensee assumes all risk of loss or damage to property of the Licensee, however caused, resulting, directly or indirectly, by reason of the installation, maintenance, use, existence or removal of said construction, and hereby releases the Railway Company from any and all liability on account of such loss or damage, whether or not the negligence of the Railway Company contributed thereto in whole or in part.

6. Insurance

The Licensee agrees to maintain insurance in favor of the Railway Company covering the liability assumed by the Licensee in Section 5 in amounts not less than $25,000 for the injury or death of one person and $50,000 for each accident covering personal injuries or death to more than one person, and in amount not less than $25,000 for property damage, said insurance to be in such form as to meet the approval of the Railway Company and placed with an insurance company which meets the approval of the Railway Company.

Notwithstanding any provision in this agreement contained, the agreement shall not become effective until the form of insurance and the company with which such insurance is placed shall have been approved by the Railway Company as above provided and shall remain in effect only during the time said insurance shall remain in effect.

7. Risk

The Licensee assumes all risk of loss or damage to free or unused property of the Licensee, on the premises of the Railway Company, however caused and hereby releases the Railway Company from any and all liability on account of such loss or damage.

8. Changes or Relocation

The Licensee shall, at its sole expense, within .... days after receipt of written notice from the Railway Company, make such changes in said construction, including relocation, as may be required by the Railway Company, if such changes or relocation shall be needed for the better development or use of the property of the Railway Company, or if such changes or relocation shall, in the judgment of the Railway Company, be needed to protect its requirements or contractural obligations, or if such change or relocation is required, directly or indirectly, by statute or by any other order of a duly constituted public authority having jurisdiction over either or both of the parties hereto.

9. Discontinuance

The Licensee shall, at its sole expense, upon abandonment or discontinuance of use of said construction, promptly remove its property from the premises of the Railway Company and restore said premises, disturbed by said construction, to a condition satisfactory to .... of the Railway Company, and upon the completion of such work this agreement shall terminate.

10. Cost of Changes

The Licensee failing to change or relocate its construction within .... days after the expiration of notice given as provided in Section 8, or remove its property as provided in Section 9, the Railway Company may, without further notice, remove, change or relocate the construction and render bills for the cost of such removal, change or relocation to the Licensee, which bills the Licensee agrees to pay on or before the fifteenth day of the month next succeeding that in which such bill is rendered.

11. Taxes

The Licensee shall pay all taxes assessed upon said construction, or on account of the existence of said construction and shall indemnify the Railway Company from the payment of such taxes.

12. Failure to Exercise Rights Not to Constitute Waiver

The failure of the Railway Company to exercise its rights hereunder upon the failure of the Licensee to perform the covenants and conditions herein contained, shall not be construed as a waiver of the covenants or conditions herein contained, but only a waiver of the particular breach, and the Railway Company may, at any time thereafter, upon the failure of the Licensee to perform the covenants or conditions in this agreement on its part to be kept and performed, exercise rights as herein provided.

13. Execution Official Act Only

The parties executing this agreement do so only in their official capacity, and only to the extent that they may have been authorized so to do, and none of the covenants herein contained are to be held or construed as their individual acts, or acts for which they may be individually liable in any way. No warranty of title to any property is given hereunder.

14. Fees and Rentals

The Licensee shall pay a fee covering the expenses in connection with the preparation and execution of this agreement and in addition thereto shall pay for the privileges herein granted as rent, an annual charge for the use of the Railway Company's property in accordance with the schedule of rental charges hereto attached and made a part hereof, marked EXHIBIT "B"—SCHEDULE, said rental to be payable in advance on date of this agreement and on anniversary date thereof; such installations made subsequent to the date of this agreement shall be prorated and adjusted for the period ending ....

15. Cancellation

The license herein given is for a period of one (1) year and thereafter, from year to year, but at all times the same may be revoked by the Railway Company for any failure of the Licensee to comply with the terms, conditions and covenants of this agreement, or may be cancelled by the Licensee, upon thirty (30) days' previous written notice to the Railway Company of such intention.

16. Successors

This agreement shall inure to the benefit of and be binding upon the parties hereto, their successors or assigns.

IN WITNESS WHEREOF, the parties hereto have executed this agreement, in ...., the day and year first above written.

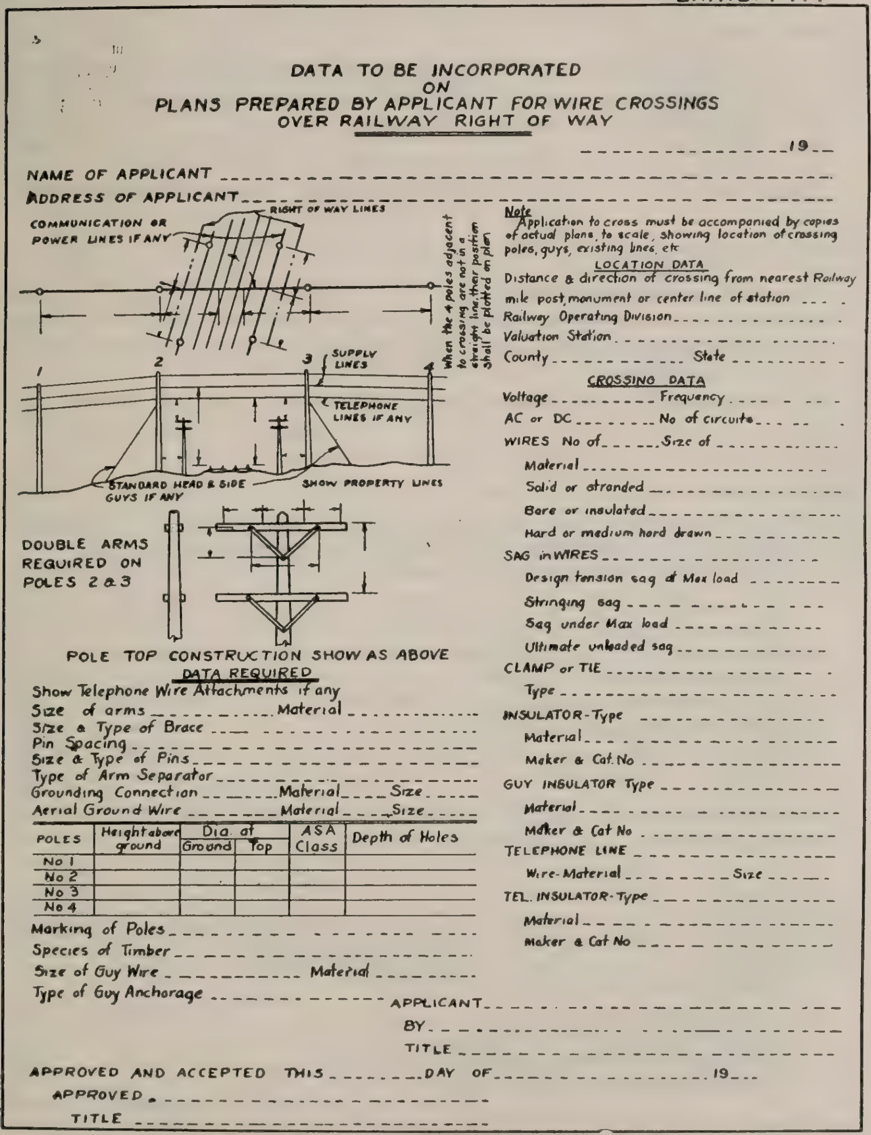
Witness: .... Company

By ....

Witness: .... Licensee

By ....

EXHIBIT "A".


RIGHT OF WAY LINES
COMMUNICATION OR POWER LINES IF ANY
When the 4 poles adjacent to crossing are not in a straight line, their position shall be plotted on plan
1
2
3
4
SUPPLY LINES
TELEPHONE LINES IF ANY
STANDARD HEAD & SIDE GUYS IF ANY
SHOW PROPERTY LINES
DOUBLE ARMS REQUIRED ON POLES 2 & 3
POLE TOP CONSTRUCTION SHOW AS ABOVE

DATA TO BE INCORPORATED
ON
PLANS PREPARED BY APPLICANT FOR WIRE CROSSINGS
OVER RAILWAY RIGHT OF WAY

________19__

NAME OF APPLICANT ________

ADDRESS OF APPLICANT ________

Note
Application to cross must be accompanied by copies of actual plans, to scale, showing location of crossing poles, guys, existing lines, etc

LOCATION DATA

Distance & direction of crossing from nearest Railway mile post, monument or center line of station ________
Railway Operating Division ________
Valuation Station ________
County ________ State ________

CROSSING DATA

Voltage ________ Frequency ________
AC or DC ________ No of circuits ________
WIRES No of ________ Size of ________
Material ________
Solid or stranded ________
Bare or insulated ________
Hard or medium hard drawn ________
SAG in WIRES ________
Design tension sag at Max load ________
Stringing sag ________
Sag under Max load ________
Ultimate unloaded sag ________
CLAMP or TIE ________
Type ________
INSULATOR-Type ________
Material ________
Maker & Cat. No ________
GUY INSULATOR Type ________
Material ________
Maker & Cat No ________
TELEPHONE LINE ________
Wire-Material ________ Size ________
TEL. INSULATOR-Type ________
Material ________
Maker & Cat No ________

DATA REQUIRED

Show Telephone Wire Attachments if any
Size of arms ________ Material ________
Size & Type of Brace ________
Pin Spacing ________
Size & Type of Pins ________
Type of Arm Separator ________
Grounding Connection ________ Material ________ Size ________
Aerial Ground Wire ________ Material ________ Size ________

POLES	Height above ground	Dia. at Ground	Dia. at Top	ASA Class	Depth of Holes
No 1					
No 2					
No 3					
No 4					

Marking of Poles ________
Species of Timber ________
Size of Guy Wire ________ Material ________
Type of Guy Anchorage ________

APPLICANT ________
BY ________
TITLE ________

APPROVED AND ACCEPTED THIS ________ DAY OF ________ 19__
APPROVED ________
TITLE ________

Exhibit "B"—Schedule

Schedule of Fees and Rentals For Wire or Cable Line Crossings Over Property of the Railway Company

License Fees

PUBLIC HIGHWAYS—Crossings confined entirely to the highway limits	No charge
PRIVATE RIGHT OF WAY AND PROPERTY—Crossings not exceeding 1,000 volts	$10.00
Over 1,000 volts but not exceeding 7,500 volts	20.00
Over 7,500 volts	30.00

Where more than one voltage is involved the highest voltage shall govern the fee.

Annual Rentals

In computing the rental to be charged for any wire or cable crossing or a crossing containing both wires and cables, where more than one item is involved and the sum of the individual rentals specified is less than the largest minimum, the rental shall be the said largest minimum.

The minimum annual rental under any agreement where a rental is involved shall be $2.00.

Aerial Wires

PUBLIC HIGHWAYS—Crossings wholly within the limits of public highways		No Rental
PRIVATE RIGHT OF WAY AND PROPERTY—Crossings not exceeding 200 feet in length, annual rentals will be as follows:		
(a) Not exceeding 1,000 volts	per wire	$ 0.50
Minimum for any one crossing		3.00
(b) Over 1,000 volts but not exceeding 3,000 volts	per wire	1.00
Minimum for any one crossing		6.00
(c) Over 3,000 volts but not exceeding 7,500 volts	per wire	1.50
Minimum for any one crossing		10.00
(d) Over 7,500 volts	per wire	3.00
Minimum for any one crossing		15.00

A proportionate additional rental calculated to the nearest dollar shall be made for any crossing in excess of 200 feet in length.

Aerial Cables

PUBLIC HIGHWAYS—Crossings wholly within the limits of public highways		No Rental
PRIVATE RIGHT OF WAY AND PROPERTY—Crossings not exceeding 200 feet in length, annual rentals will be as follows:		
(a) Not exceeding 1,000 volts	per conductor	$ 0.05
Minimum for any one crossing		3.00
(b) Over 1,000 volts but not exceeding 3,000 volts	per cable	3.00
Minimum charge for any one crossing		5.00
(c) Over 3,000 volts but not exceeding 7,500 volts	per cable	4.00
Minimum charge for any one crossing		7.00
(d) Over 7,500 volts	per cable	6.00
Minimum charge for any one crossing		10.00

A proportionate additional rental calculated to the nearest dollar shall be made for any crossing in excess of 200 feet in length.

Underground Wires and Cables and Conduit for Electrical Conductors

PUBLIC HIGHWAYS—Crossings wholly within the limits of public highways		No Rental
PRIVATE RIGHT OF WAY AND PROPERTY—Crossings not exceeding 200 feet in length, annual rentals will be as follows:		
(a) Not exceeding 1,000 volts	per conductor	$ 0.025
Minimum for any one crossing		2.00
(b) Over 1,000 volts but not exceeding 7,500 volts	per conductor	1.00
(c) Over 7,500 volts	per conductor	2.00
(d) Spare or unoccupied ducts or pipes	each	0.50
When the duct shall be occupied in the future by a cable, the annual rental charge for the cable shall govern and the 50 cents charge shall cease.		
(e) Ducts or pipes carrying conductors		No Rental

A proportionate additional rental calculated to the nearest dollar shall be made for any crossing in excess of 200 feet in length.

Discussion on Economics of Railway Labor

(For Report, see pp. 291–310)

(President Hastings presiding)

Chairman G. M. O'Rourke (Illinois Central): Committee 22—Economics of Railway Labor presents reports on four of the nine assigned subjects. The committee reports progress in study for subject 3, The relative economy of combined vs. separate bridge and building gangs; Subject 5, Review and revise factors previously established for equating track values for labor distribution; Subject 6, Labor economies possible through the use of highway motor vehicles for maintenance forces; and Subject 7, Added labor economies resulting from use of off-track maintenance equipment.

Subject 2, Analysis of operations of railways that have made marked progress in the reduction of labor required in maintenance of way work, has been studied by this committee for several years by observing practices on different railroads. The report this year covers the track supervisor system in effect on the Chicago, Burlington & Quincy and the Chicago, Rock Island & Pacific. Mr. H. A. Cassil, chairman of the subcommittee, will present the report.

Mr. H. A. Cassil (Pere Marquette): This report is too long to read, but the study was very interesting to the committee and indicates that the track patrol systems on these two roads were the result of a great deal of study. We found, on going over those roads, that all concerned with it "were sold on it." They were in favor of it. It is rather different than the methods of track patrol on other railroads. To those who have not read the report, I suggest it might furnish food for thought. It might not be just the thing for all the roads—probably it wouldn't be—but there are elements in it that are very well worth studying.

I would like to call attention to a misprint on page 294 in the second of the conclusions. This should read: "It provides closer day-to-day supervision over and", instead of "the", "cooperation with the foreman, again contributing to increased production and promoting a uniformity of work."

President Hastings: This report is offered as information. Is there any discussion? It will be so received.

Chairman O'Rourke: Subject 4, The effect of modern equipment and machines on bridge gang organization and efficiency, is submitted after two years of study of the practices on almost 200,000 miles of railroads throughout the United States and Canada. Mr. J. S. McBride, chairman of the subcommittee, will present the report.

Mr. J. S. McBride (Chicago & Eastern Illinois): This report is found on page 295. In its compilation the committee had before it information furnished by 42 railroads as to modern equipment and machines used by bridge gangs. Tables 1 to 6 contain a list of such equipment on each road in accordance with the practice of the road, of assigning such equipment to specialized gangs, to combination gangs or to definite territories. This assignment varies according to the size of the road and local conditions. The tables illustrate the extent to which different roads have gone in equipping bridge gangs with power equipment and tools and should be of value to any road desiring to compare its equipment with that of other roads.

The use of this equipment has had varying effects upon bridge gang organization but has led to no definite trend. In some cases there has been no change in organization. In other cases it has resulted in a reduction of the number of gangs or a reduction in size of gangs, while in others it has resulted in the substitution of mechanics for laborers. This equipment tends to raise the standard of workmanship and requires a better trained organization and a closer supervision in programming work to insure that equipment is used to the best advantage at all times.

On pages 300 to 305 are shown the labor savings that have been accomplished by machines in the performance of certain work. The efficiency of bridge gangs is increased because modern equipment enables them to perform certain operations in less time than the work could be done by other methods. The report is submitted as information.

President Hastings: You have heard this portion of the report. It is submitted as information. The conclusions are found on page 305 and sum up the situation with reference to this particular topic. They should receive some discussion. Is there any discussion? They must be pretty good conclusions, Mr. Chairman. They will be received as information.

Chairman O'Rourke: Subject 8 is Labor economies which may be effected through revision of operating and maintenance of way and structures rules. This subject has been studied on eight representative railroads, one eastern, three southern, one western and three southwestern, and it is believed to be representative. Mr. F. S. Schwinn, chairman of the subcommittee will present the report.

Mr. F. S. Schwinn (Missouri Pacific): Your committee has reviewed those maintenance of way and structure rules having particular reference to flagging requirements and the operation of motor cars and similar equipment. For the reasons stated in this report, we have made no recommendations for the revision of the rules.

The study of the subject developed the fact that certain savings for labor could be effected if forces were relieved of the necessity of providing flag protection on light traffic branch lines where not more than two scheduled train movements were operated during the working hours and that complete safety could be maintained by the issuance of appropriate train orders or time-table instructions as indicated in the report.

An analysis of the performance on eight railroads, having a total of approximately 33,000 miles, of which nearly 8,000 miles were classed as light traffic branches, indicated that about $20 in labor per mile of light traffic branch might be converted annually from unproductive to productive effort.

Because of the divergent views and expressions received by the committee, only generalized suggestions have been made. A more definite recommendation could be made only by giving consideration to an individual branch or district in the light of its operating requirements and maintenance practices. This report is presented as information.

President Hastings: Is there any discussion of this portion of the report? It will be received as information.

Chairman O'Rourke: Subject 9 is Economies in labor resulting from the reduction in track patrol made possible through improvements in track conditions. Improvements in materials and design of track facilities have affected maintenance of way practices in many ways, especially in the manner and necessary frequency of track walker inspection. Mr. F. J. Bishop, chairman of the subcommittee, will present the report.

Mr. F. J. Bishop (Toledo Terminal): This report will be found on pages 308, 309 and 310.

(Mr. Bishop then read the first paragraph on page 308.)

Mr. Bishop: This tabulation indicates in considerable detail the methods used in track patrolling by the various roads, shows general practices, and does not imply the absence of variations to suit conditions on the part of the roads supplying the information. Many changes have taken place in methods of track patrol in recent years, because of the costly improvements that have been built into the track structure.

On page 308 are listed the reasons given by maintenance officers for having changed their methods of track patrol. On page 309 is an analysis of the methods used by the various roads, condensed. This tabulation shows 11 roads, 40.5 percent of the mileage, using irregular or weekly patrol; 9.7 percent of the mileage, three patrols per week; and 30.6 percent of the mileage working days only; with 19.2 percent of the mileage reporting showing daily patrol.

On page 310 are two conclusions which we think contain the meat of the report:

> "1. A study of the methods and amount of necessary work that is accomplished by a track patrol is well worth the time and effort.
>
> "2. Large economies in labor have been effected by a reduction in track patrol made possible by improved track and roadbed conditions."

This report is offered as information.

President Hastings: Is there discussion? If not, it will be so received.

Chairman O'Rourke: Subject 1, Revision of Manual was given due consideration, and no revisions are recommended.

That concludes the report of Committee 22.

President Hastings: We have just heard another splendid report, and I make special mention of it and call particular attention to it because it is on this subject of economics. There isn't any subject that should be a more live subject before us these days than this question of economics, even though some of our political and semi-political friends and neighbors may think the word "economics" has been taken out of the dictionary. The railroad companies are spending huge sums annually in non-productive time.

The studies that this committee has given in the phases of the subject touched on this year should be taken home with you and pondered over for your own individual profit. This committee has done a fine piece of work as it always does. The committee is excused with the thanks and appreciation of the Association. (Applause)

Discussion on Ties

(For Report, see pp. 647–656)

(President Hastings presiding)

Chairman John Foley (Pennsylvania): In the report of Committee 3—Ties, all the matter presented is submitted for information only. There are no recommendations on which the Association has to act.

For revision of the Manual there are no recommendations. Subject 2, Extent of adherence to specifications, is presented as information. Unfortunately, the chairman of the subcommittee, Mr. Duncan, is not present. We relied upon him to make a statement in connection with this subcommittee report. I can say that it follows the usual procedure of recording our reactions to the ties which were observed during the year. We found that the ties accepted by the various railroads visited were not all perfect, but the inspection proved that any railroad making a real effort to get ties in accordance with AREA standards has no difficulty in doing so.

Subject 3, Substitutes for wood ties, is covered by a tabulation of ties that have been installed as tests of materials other than wood. It brings up to date all the tests that have been reported. Presented in alphabetical arrangement, it will provide useful information for those who wish to study that particular subject.

Subject 4: Tie renewal averages and costs per maintained mile were presented in the June–July Bulletin of the Association and are therefore not repeated.

Subject 5, Proper seasoning of oak ties with special reference to those grown in southern lowlands, is reported by the statement emphasizing the difficulties that have been experienced in getting tangible results from the experimental work that has been done. Owing to the cost of carrying on this work, it is recommended that the subject be discontinued and made a part of another study that the committee is considering.

Subject 6 is Investigate and report on the dimensions of ties and bring up to date the information presented in the 1924 and 1932 Proceedings. Appendix E contains the report of that subcommittee which will be commented upon by Mr. Burton as chairman.

Mr. W. J. Burton (Missouri Pacific): This report is largely statistical. There are certain facts which seem to be indicated, among which is the very wide use of the AREA standard sizes. There are only one or two large railroads which do not adhere to the standard specification sizes. The report indicates, as is well known, that there has been a considerable trend toward the larger size. When this report is compared with previous compilations of this kind, this fact stands out.

There is another fact that this report indicates, and that is that the choice of length is largely a matter of custom in the different regions. For instance, if you examine the tabulation on page 651, you will notice that, in the southern region, with the exception of certain roads subsidiary of the Illinois Central, the 8½-ft. length is practically universal, whereas if you cross the Mississippi river over into the southwestern region, you find that the use of the 8-ft. ties is universal, with one very minor exception.

This matter of length seems to be one of adherence to past custom rather than a choice of the best length. The committee has previously shown that the short tie, that is, the 8-ft. tie, is not nearly as efficient as an 8½ or 9-ft. tie, largely because so much of the center of the track must be left untamped in order not to have center-bound track, and the ballast is wasted with the shorter ties to a much greater extent than with the longer ties. The additional six inches added to the length of the tie permits tamping that much more of the tie between the rails, so the effective increase in support is double the increased length.

One or two roads have recently recognized this fact, particularly the Santa Fe which has within the last day or two adopted a length of 9 ft. as standard for main lines. The studies which we have reported previously indicate that that is a move in the right direction.

President Hastings: Is there any discussion of this part of the report? Mr. Burton brings out some very interesting points. Is there anything further that you can say about that, Mr. Burton, other than what you have already said?

Mr. Burton: I think this matter of length is of very considerable importance, particularly with the present-day necessity of strengthening track for higher speeds. An increase in track strength and support, by increasing the length of the tie, can be obtained at much less cost than by any other means.

President Hastings: Thank you, Mr. Burton.

Is there any discussion? If not, this portion of the report will be received as information.

Chairman Foley: Subject 7, Cause and control of splitting in railroad ties, will be commented on by Chairman Butler.

Mr. R. E. Butler (Newburgh & South Shore):

The subject has been separated into:

1. Why and how does wood shrink?
2. When and where do ties split?
3. How do splits affect the service?
4. What procedure should be followed to minimize the splitting of ties?

The shrinkage of wood and the resulting stresses are being studied in laboratories with the idea of developing some method of controlled seasoning; but, to the lack of definite information on the subject doubtless is due the fact, that, while most roads use some type of anti-splitting devices, the method of their application, the number used, and their design vary more than seems necessary.

Carefully controlled tests of devices in ties, seasoning under usual conditions, are needed to determine the efficiency of the various practices now in use to minimize splitting. Only through further study and experiment can definite conclusions as to proper procedure be drawn.

This report is presented as information regarding the progress in the study of the subject, with the recommendation that the subject be continued.

President Hastings: If there is no discussion of this portion of the report, it will be received as information.

Chairman Foley: That completes our report.

President Hastings: Mr. Foley, you and your committee have brought in a splendid report, as you always do. We compliment you on the fine work that you are doing and hope that some day in your swings through the country, with your little inspection group, you will find everybody adhering to the specification.

The committee is excused with the thanks of the Association. (Applause)

Discussion on Highways

(For Report, see pp. 311–318)

(President Hastings presiding)

Chairman J. G. Brennan (Association of American Railroads): The committee will report first on Subject 2, Design and specifications for highway crossing at grade over railway tracks, both steam and electric, collaborating with Committee 1—Roadway and Ballast, and with American Society of Municipal Engineers and American Transit Association. Mr. W. J. Hedley, chairman of the subcommittee, will present the report.

Mr. W. J. Hedley (Wabash): This specification is for the construction of monolithic concrete crossings. In the first heading, "General", there is some rather significant material, which I will read.

(Mr. Hedley then read paragraph one in full and the next three paragraph headings on pages 312 and 313.)

President Hastings: You understand, gentlemen, as the chairman of this subcommittee proceeds, if you have comments to make on the subjects under these headings which he presents to you, please rise and make them.

(Mr. Hedley then read the balance of the paragraph headings.)

Mr. Hedley: There being no comments, I move the adoption of this report for publication in the Manual.

(The motion was seconded, put to a vote and carried.)

Chairman Brennan: Subject 4, Develop drawings showing general requirements for installation of automatic gates, was presented as completed at the convention last year, and the committee now recommends that the subject be discontinued, as it has already been adopted and published in the Manual.

President Hastings: That matter will lie with the Committee on Outline of Work as to the continuance or discontinuance of the subject.

Chairman Brennan: Subject 5, Method of classifying grade crossings with respect to hazard, appearing as Appendix B, is a very important subject on which the committee reports progress, with recommendation that the subject be continued. Mr. E. R. Lewis, chairman of the subcommittee, will present the report.

Mr. E. R. Lewis (Michigan Central): This report is a repetition of the report that was presented last year, with the exception of some corrections and a suggestion as to the consideration of accidents in this connection. The report is submitted as a progress report.

President Hastings: You have heard that the report is submitted as progress and information. Have you any comments to make thereon? Is there any discussion? It will be so received, Mr. Lewis.

Chairman Brennan: The next subject is, No. 7, Lamps on manual and automatic crossing gates, collaborating with Signal Section, Appendix C. This is complete with a recommendation for its publication in the Manual, upon the completion and adoption by the Signal Section of specifications for the design of the lamp unit and the operating mechanism.

Since the publication of this report, there has been some criticism in regard to the number of lamps recommended on the manually operated crossing gates. Mr. B. J. Schwendt, assistant signal engineer of the Big Four, thinks the report is not consistent in that we recommend for automatic crossing gates, one steadily burning light on the end of each gate arm, and two red lights that flash alternately, whereas on the manually operated crossing gates, we recommend that one or more lamps shall be provided on each gate arm, facing the highway for night indication only, so arranged, so far as practicable, as not to be visible from the track.

The committee has given consideration to the criticism. It is the consensus of the committee that there are many locations where it is not necessary to have three red lights on manually operated gates and that the report as submitted will adequately cover the requirements. Discussion is invited. The committee will be glad to hear from anybody who disagrees with the report or has any suggestions to make.

If there is no discussion, it is recommended that the report be published in the Manual as recommended practice, upon the completion and adoption by the Signal Section of specifications for the design of the lamp unit and the operating mechanism. I so move.

(The motion was seconded, put to a vote and carried.)

Chairman Brennan: Subject 8, Striping of crossing gates, Appendix D, will be submitted by Mr. G. P. Palmer, the chairman of the subcommittee.

Mr. G. P. Palmer (Baltimore & Ohio): One of the assignments for Committee 9 was to prepare a drawing to show the standard method of striping highway crossing gates for use on both automatic and manually operated gates. You will find such a drawing on page 318. This drawing was prepared after receiving replies to the questionnaire that was sent out to members of the committee and the manufacturers and is, in fact, a compromise of the various replies that we received.

However, since the publication of this plan, we have had one criticism to the effect that the drawing should show the right-hand gate arm rather than the left-hand gate arm, as that is the one that is normally seen by a motorist approaching a crossing. To accomplish that, all that it is necessary to do is to turn this picture or plan around. The same information will govern whether it is right or left. The committee feels that the suggestion is proper and therefore recommends that the plan be turned around to show the right instead of the left gate and be adopted for publication in the Manual. I move that this be so adopted.

(The motion was seconded, put to a vote and carried.)

Chairman Brennan: That completes the report of Committee 9.

President Hastings: Is there any discussion of this committee's report as a whole? Mr. Brennan, the Association thanks you for the work which you and your committee have done. You are excused at this time. (Applause)

Discussion on Economics of Railway Location and Operation

(For Report, see pp. 57–171)

(President Hastings presiding)

Chairman H. M. Stout (Northern Pacific): Thirteen subjects comprise the agenda of this committee for the past year. Three of these have included collaboration with other committees of this Association, or another division of the Association of American Railroads.

In addition, collaboration was required in the study of two subjects included in the assignments of other committees. All of these matters have been given due consideration during the year, with the result that the report which is being offered includes presentations pertaining to 11 assignments. The reports of three of these subjects are offered as final reports, with recommendations for the Manual; also, a final report with recommendations for revision of the matter now in the Manual devoted to II Power.

Four years ago a careful résumé of the part of Chapter 16 designated as Part II Power was undertaken for the purpose of revising it by substituting fundamentals expressed in accord with modern experience and thought. Three progress reports have been presented in which the proposed revisions have been given progressively. In Appendix A we are now submitting a final report with recommendations, which will be presented by Mr. E. E. Kimball, chairman of the subcommittee.

(Vice-President Geo. S. Fanning assumed the chair.)

Mr. E. E. Kimball (Schenectady, N. Y.): The report which is now proposed for the Manual is a condensation of that submitted last year. It is intended to replace the material now appearing under the heading II Power on Manual pages 9 to 24 inclusive, of Chapter 16.

The new material contains about twice as many pages as the old, but it covers Diesel-electric locomotives, electric braking and a discussion of speed-time-distance and fuel calculations which are not covered in the present Manual.

A considerable portion of the report is taken up with explanations for the purpose of pointing out some of the fundamental differences in the various types of motive power in order that locating and operating engineers who have had no design experience will be better prepared to make preliminary estimates of the comparative performance and economic advantages of any of the principal types of motive power.

Another reason for the explanations is to acquaint those who have had design experience with the fundamental principles on which the comparisons are made, in order that they can make adjustments along practical lines when specific cases are involved.

The advantages of the new method are: It can be applied before design data are available; the calculations are simple and, when arranged in tabulation form, they are handy for easy reference and comparison; and the methods applying to the several types of motive power are similar, which is an advantage when comparing different types.

The report is rather long and, for this reason, we think it will be sufficient to mention briefly some of the important points which are covered, without commenting on the material it is intended to replace.

The statements under general principles outline the fundamental purpose of all locomotives and define the boundaries which limit their power and speed. Because the manner in which power is applied varies with different types of motive power, it is essential that the measurement of this power be referred to some point which is common to all types, namely, the driving axle.

Figures 1 and 2 illustrate the chief difference between steam and electric locomotives, which is due to the fact that in one case the source of power is limited, whereas in the other case the source of power has relatively unlimited capacity. Other differences are discussed later in the report when reference is made in turn to the different types of locomotives.

The report emphasizes the fact that in practice, locating and operating engineers are chiefly concerned with the weight, tracking qualities and capacity or power because these factors determine to a large extent the character of roadbed, track, track structures and alinement required for successful operation.

About the only practical way to obtain these qualities in a locomotive is to vary the wheel arrangement to suit conditions. For example, the capacity of a locomotive will depend upon its weight or vice versa, and the number of axles will depend upon the total weight of the locomotive and the allowable weight per axle. The tracking qualities of a high speed locomotive must be superior to those for a slow speed locomotive; consequently, special consideration must be given to adequate means for guiding locomotives around curves, that is, by the addition of guiding and trailing trucks. These extra axles serve more than a double purpose because they are useful in supporting additional weight which allows the capacity to be increased as well as improving the guiding qualities of the locomotive.

Table 1 shows how the various classes of steam locomotives naturally arrange themselves in groups according to the ratio of their weights on drivers to the total weight of the engine. In some cases there is a sharp division between classes and in other cases there is an overlap.

The horsepower capacities which appear in the third column are based on three-fourths of the maximum capacity obtained from tests, where tests were available and apply to recent designs equipped with modern economy devices. Some of the less modern locomotives can be counted on for the horsepowers derived from the table under maximum test conditions, but they cannot be counted on to perform in service according to these capacities. The capacity of older locomotives must be discounted still further or determined from design data.

The second column of the table gives the ratio of the weight on drivers to the total weight of engine and tender in order to arrive at an approximate weight of tender to be included in the total weight of locomotive and train.

Facsimiles of Forms A and B are shown, together with an example illustrating the application of Form B to an actual locomotive. These forms are based on uniform firing rates and constant evaporations corresponding to normal capacity and apply to all speeds above V_1. The normal capacity is assumed to be three-fourths of the maximum, or the normal horsepower can be obtained from Table 1 if the maximum is unknown. Development of these forms has been described in previous reports.

Vice-President Fanning: This material, you understand, is being offered for the Manual: I suggest that, as we finish each natural division, an opportunity be given for discussion because at the end you will be voting on all of this material for the Manual. Is there any discussion on the material on steam locomotives? If not, proceed, Mr. Kimball.

Mr. Kimball: The report describes a number of distinct types of electric locomotives and contains forms for calculating the speed-tractive-effort curves and substation output for three different types. Characteristic curves of some of the principal types are shown for ready comparison.

In the case of electric locomotives, practical methods have been developed for electric braking by using the motors to generate electric power and return it to the distribution system or waste it in resistances. A form is included for calculating the capacity and characteristics of the equipment when returning power to the trolley instead of taking power from the trolley. That concludes the information on electric locomotives.

Vice-President Fanning: Any discussion on the electric locomotive section?

Mr. Kimball: In principle, oil-electric locomotives are practically the same as steam locomotives except that they resemble electric locomotives in appearance and have some of the characteristics of electric locomotives as well as some of the characteristics of steam locomotives. They are usually classified the same as electric locomotives but they are limited in capacity by their source of power the same as steam locomotives.

Their operation is practically automatic, based on constant output of the engine; consequently, their characteristics can be closely estimated and verified. This completes the section on oil-electric locomotives.

Vice-President Fanning: Is there any discussion?

Mr. Kimball: Speed-time-distance calculations are quite generally known, but for those who are not familiar with them and who would have to refer elsewhere for an explanation, we have added a sample form and discussion on how to proceed to this year's report.

Your attention is called to a correction in the table at the bottom of page 83. The heading of the left-hand column should be changed to read "miles" instead of "miles per hour."

On the next page we have introduced the Davis Train Resistance Formulas because they have been tested over a wide range of conditions and are generally accepted throughout the United States and Canada.

I move the report be accepted for printing in the Manual superseding pages 9–24, inclusive, of Chapter 16 of the Manual under the heading Power.

(The motion was seconded.)

Vice-President Fanning: You have heard the motion for the adoption of material on Power contained on pages 58 to 91. Is there any discussion?

Mr. F. R. Layng (Bessemer & Lake Erie): I simply want to commend the chairman of this subcommittee and the entire committee for a very valuable piece of work. I hope this motion will prevail.

(The motion was put to a vote and carried.)

Chairman Stout: The second subject considered was Methods for obtaining a more intensive use of existing railway facilities. The series of reports which have been presented heretofore has included discussions and information on a considerable number of studies under this assignment. The subject is a very practicable one. The discussion of the sub-topic considered last year is presented in Appendix B as information and a progress report. It will be presented by Mr. L. E. Dale, chairman of the subcommittee.

Mr. L. E. Dale (Association of American Railroads): The report this year covers the consolidation of two railroads, the West Jersey & Seashore, which was part of the Pennsylvania, and the Atlantic City Railroad which was part of the Reading. Up until about 1929 these two separately operated railroads were used to about their capacity during periods of heavy passenger traffic. After that there was less to do, and studies were made as to possible economies that could be secured from consolidation. Savings amounting to $1,569,349 were estimated as obtainable, which was probably 16 to 20 percent of the total operating expenses. These economies were secured by savings from abandonment of duplicating lines, terminal switching, passenger and freight service, and general supervision. There were some small savings incidental to these.

The railroads were consolidated June 26, 1933. While it has never been possible to determine just what the economies from consolidation were because of the very great drop in business, passenger traffic falling off 75 percent and freight about 50 percent from what had been normal traffic previously, there were undoubtedly very great savings made. A statistical table sets forth briefly the results obtained in 1937 by the consolidated properties compared with results with separate operation in previous periods. This is presented as information.

Vice-President Fanning: Any discussion on this report? If not, it will be received as information.

Chairman Stout: Subject 3 is: Methods or formulas for the solution of special problems relating to more economical and efficient railway operation. The report here presented on this assignment, included as Appendix C, is, in effect, a continuation or a second chapter of the progress report given at the last convention on the subject "Economical relation between the track structures and traffic to be handled," and gives the conclusions reached in a study of the questions raised in the former report, as to the accord of experience with the adopted formulas governing allowances for increased or decreased use.

Mr. C. H. R. Howe, chairman of the subcommittee, will present the report on this subject.

Mr. C. H. R. Howe (Chesapeake & Ohio): In the previous report on this subject presented at the last convention and printed in the Proceedings, Vol. 40, attention was called to the fact that expenditures for roadway and track laying and surfacing labor apparently were not in accord with the formulas governing allowances for increased or decreased use set forth in the Manual, pages 21–9 to 21–14, inclusive. These formulas to which we refer are popularly known as the Yager formulas. This naturally raises the question as to whether or not the formulas are in need of revision.

Since the publication of the original report, supplemental data have become available which are discussed briefly in this report, and are shown in the tables.

After a thorough study of this additional information, and the data previously published covering the period 1927 to 1936 inclusive, the committee is of the opinion that the fundamental principles set forth in the formulas are sound and require no revision. There are, however, certain factoral adjustments that should be given consideration in the application of the formulas. Certain changes have taken place in the "Percent Affected by Use" values given in the tables shown on pages 21–12 and 13 of the Manual. However, the respective percentages for the various accounts have always been subject to adjustments by the individual railways and in no wise affect the principles of the formulas.

In reviewing the various items that have been discussed in connection with the reduction in hours required for track laying and surfacing, it is evident that there is a wide range for variation in the contributory factors in any given case, and that any effective analysis of an individual railroad's results is peculiar to the railway in question.

The committee has arrived at the conclusion that no revision of the subject matter in the Manual is considered necessary at this time, and presents this report as information.

Vice-President Fanning: Is there any discussion? If not, Mr. Stout, you may proceed with the next subject.

Chairman Stout: The next subject assigned is, Methods for determining most economical train length, considering all factors entering into transportation costs. This was initially assigned in 1928 and five progress reports of information have been presented. The current report, Appendix D, consists of a résumé of those preceding, and conclusions for publication in the Manual.

Mr. W. B. Irwin, chairman of the subcommittee that handled this subject, is unable to be present this morning. Therefore, in his absence, the report will be submitted by Mr. Rose, a member of the subcommittee.

Mr. L. S. Rose (Peoria & Eastern): The report of this subcommittee speaks pretty much for itself. As pointed out by the chairman, we have had the subject for more than ten years, and this time we are presenting some tables and subject matter for the Manual. The part we desire to have put into the Manual begins on page 101, and includes the tables and the reading matter on the following pages. The foundation is shown in the first part of the report. A digest has been made of the reports made on this subject from 1929 to date.

I move that the matter on page 101 beginning with "Methods for Determining Most Economical Train Length, Considering All Factors Entering into Transportation Costs" to the end of the report be published in the Manual.

(The motion was seconded, put to a vote and carried.)

Chairman Stout: Subject 6 is Effect of inland waterway transportation on the economics of railway operation. The second progress report on this subject of great complexities is submitted as Appendix E. Mr. J. E. Teal, chairman of the subcommittee, will present the report.

Mr. J. E. Teal (Chesapeake & Ohio): Your committee made its first report under this assignment at the convention last year, and outlined in brief a history of river and canal transportation, together with statistics of the lengths and controlling depths of principal waterways located in the United States. The report also contains statistics of the water-borne commerce on the inland waterways of this country, the total federal expenditures authorized. and "additional amounts required to complete"; as of June 30, 1937, that are allocable to improving and maintaining the inland waterway system.

It is the object of this committee, as a fact-finding agency, to compile information in connection with the cost of providing and improving the most important of the inland waterways, the volume of traffic transported thereon, and, in short, the economic justification of such expenditures, related to the economic effect of diverting freight traffic from the railroads to the waterways on railway operation. A number of projects have been suggested for study, and reports are presented at this time covering the Ohio river, the New York State Barge canal, and the proposed Lake Erie–Ohio River canal.

Time will not permit an explanation in detail of these reports. However, I shall briefly point out the portions that should be given careful attention.

On pages 107 to 110, inclusive, will be found a discussion concerning the public interest, economics of inland waterway transportation, economic yardstick, comparative costs, comparative adequacy, reliability, continuity of service, and extent of government assistance.

Beginning on page 110, a brief description of the Ohio River system will be found. This portion of the report extends through to page 135. A map showing the general location and territory traversed by the Ohio River system is inserted between pages 110 and 111. Fig. 2, following page 112, is a tabulation and chart showing tonnage graph of the Ohio river for the year 1936. This is a very interesting figure, and it shows that the tonnage moving on the Ohio river consists mainly of coal and coke, oil and gasoline, and iron and steel. Fig. 3, page 114, shows the commercial statistics for the Ohio river for the period 1890 through 1938, and Fig. 4, following, is a graphical chart showing the same information. Tables 1 and 2, page 115, show the extent of the federal government's investment in the Ohio river to June 30, 1938, amounting to a total in excess of $140,000,000, the annual carrying cost amounting to over $10,600,000, and the tonnage handled, for the years 1928 to 1937, inclusive.

Similar data are shown on pages 116 to 129, inclusive, for the improved tributaries of the Ohio river, of which the Tennessee river is the most important in so far as future development is concerned.

The existing project, as reported in the Annual Report of the Chief of Engineers for the year 1938, provides for a channel nine feet deep at low water, from the mouth to Knoxville, Tenn., a distance of 648 miles, to be obtained by the construction of low dams; also, under the provisions of the Federal Water Power Act a high dam with locks may be substituted for any two or more of the low dams and built by private interests, states, or municipalities; and provides further, that in case high dams are built before the United States shall have built the projected locks and low dams which are to be replaced, the United States shall contribute to the cost of the substituted structures, an amount equal to the estimated cost of the works of navigation for which substitution is made. The report lists a total of 37 proposed locks and low dams, and such existing locks and dams as are included in the project, together with the estimated or actual cost, aggregating over $132,000,000, which includes the actual cost of Wilson Dam No. 2, of $46,666,648.

The Tennessee River project, of course, is tied in with the Tennessee Valley Authority, which has been the subject of congressional and nation-wide debate during the past few years. In this connection, I wish to quote from the March, 1940, issue of "The Nation's Business" a portion of an article entitled "The Case for Light and Power," which has particular reference to the improvement of the Tennessee river for flood control and navigation:

> "For flood control and navigation—and incidental power—TVA will remove from production and from the tax rolls, according to its own figures, practically 1,000,000 acres of rich bottom lands. Most of this will be permanently drowned out. The greatest inundation in recorded history briefly covered only 541,000 acres of Tennessee valley.
>
> "To control high water, TVA superimposes above the operating head for its hydro plants, storage space for 8,928,000 acre-feet of water. But, before it drowned out the valley, there existed in natural channel storage, the bottom lands annually renewed and refreshed by spring freshets—some 14,600,000 acre-feet. Thus, after it had harnessed the river for power, TVA has actually created a net deficit of flood storage space of 4,500,000.
>
> "Ironically enough, most of the flood danger is at Chattanooga where army engineers propose to build a $20,000,000 flood wall to protect the city from TVA's flood 'controlled' river!
>
> "Yet TVA charges off from its power bill $100,000,000 to flood control.
>
> "The 640 miles which TVA proposes to provide with a nine-foot channel to Knoxville will cost at the rate of $180,000 a mile. By the methods used by the army engineers, the Ohio was given a nine-foot channel from Cairo, Ill., to Pittsburgh, 973 miles, at a cost of $130,000,000, or $133,000 a mile. The army estimated the cost of a nine-foot channel on the smaller Tennessee at $117,000 a mile.

> "By building a series of low dams, a nine-foot channel to Knoxville could be created at a cost of $75,000,000 according to official army engineer estimates. Such a channel would be adapted to the low-sill barges that ply the confined channels of inland waterways but can navigate the great open water lakes of the TVA only at considerable risk.
>
> "Bona fide friends of navigation and flood control object to the misuse of these objectives to give legal color to the power program and to reduce the capital base upon which 'cheap' power rates of TVA are predicated.
>
> "Yet TVA charges off from its power bill $115,000,000 for navigation.
>
> "Thus, for not more than $155,000,000, according to official estimates, the two legitimate objectives of TVA could have been accomplished. By adding power, TVA has increased its cost to at least $500,000,000."

Your committee does not believe that flood protection and navigation are two legitimate objectives of the TVA that can be economically justified. More recent estimates place the total cost of improving the Tennessee river for navigation, without regard to TVA accounting, at $88,716,193, or $137,000 per mile. Even on this basis it is inconceivable to believe that traffic density will increase five times, or to a point where it will effect a ton-mile cost of less than 2.3 cents, as shown in Table 31. In fact, there is no doubt that the completion of this project will add to the cost of the nation's transportation bill. This project will be the subject of study for future report.

Table 31, following page 128, shows a summary of the cost of maintenance and operation of the Ohio river and its tributaries for the year 1938. From this summary it will be noted that the total investment to June 30, 1938, aggregated over $234,000,000, and that the total annual carrying cost, including maintenance, interest on investment, and tax exemption, amounted to $16,900,000. Interesting factors are the ton-mile costs as borne by the government and borne by the users. The cost per ton-mile borne by the government is a calculated figure, and ranges from a minimum of nine-tenths of a mill on the Monongahela river to a maximum of 33.1 cents on the Little Kanawha river. The average cost per ton-mile borne by the users has been estimated at four mills, which, in the opinion of your committee, is very conservative, when all factors influencing costs are taken into consideration.

The next section of the report, the New York State Barge canal, beginning on page 130, includes a brief, early history of the canal, followed by a discussion as to the development of the barge canal system, and a map on page 132 showing its general location. The tables on pages 133 and 134 show the investment expense, maintenance and operation expenses. It will be noted on Table 3, page 134, that the transportation cost per ton-mile over a period of years has ranged from a maximum of 29.92 mills in 1922 to a minimum of 12.37 mills in 1931. In 1937 it was 13.24 mills.

The next section of the report is of considerable interest, and Mr. Forsberg, chief engineer of the Pittsburgh & Lake Erie, will present this section of the report.

Mr. R. P. Forsberg (Pittsburgh & Lake Erie): The subcommittee's report on Proposed Lake Erie and Ohio River canal is found on pages 135 to 149, inclusive. The first three and one-half pages are devoted to a history of the proposed canal, from 1830 to the submission of the report of the chief engineer of the United States Army on the project to the secretary of war on January 23, 1939. This is followed by a description of the proposed waterway. A map and profile of the proposed canal is attached to the report.

Very briefly stated, the proposed waterway would extend from Beaver, Pa., on the Ohio river to Lake Erie, a distance of 104.6 miles. The canal channel would have a minimum depth of 12 ft. and, with the exception of an eight-mile stretch through the city of Youngstown, Ohio, a minimum channel bottom width of 250 ft.

The Board of Engineers for Rivers and Harbors has estimated that the entire cost of the project will be $240,066,000. A committee composed of the chief engineers of seven of the steam railroads whose interests would be adversely affected by the construction of such a waterway, of which committee the speaker is chairman, has made careful estimates of the cost of the proposed project, bringing the construction cost to the December, 1938, level, which estimates indicate that the total cost of the project would be approximately $386,000,000, or a per-mile cost of approximately $3,675,000. This committee concludes its report by stating that:

> "Analysis of all information pertaining to the proposed Lake Erie–Ohio River canal available to the committee shows beyond all doubt that from a strictly financial viewpoint, the proposed canal cannot be economically justified, and its construction at the expense of the taxpayers of the United States is not warranted."

The President of the United States, under date of February 16, 1939, requested the Interstate Commerce Commission to submit a report covering certain aspects of the report of the Board of Engineers for Rivers and Harbors, and on October 27, 1939, the Interstate Commerce Commission submitted its report to the President. This report was not released for publication until January 26, 1940. The Interstate Commerce Commission's report is a document of 67 mimeographed sheets with appendices setting up tabulations of various pertinent data. I have read this report in its entirety, and it is unquestionably adverse in its findings.

Mr. Teal: General conclusions will be found on page 149, which point out that traffic moving on the inland waterways comprises tonnage that would ordinarily move by rail if the inland waterways were not available, and that the cost of transportation on the Ohio river and the New York State Barge canal is in excess of the cost of rail transportation; also, that the proposed Lake Erie–Ohio canal cannot be economically justified.

In concluding, I wish to call attention to one or two factors which measure railroad operating results during the past few years. Net income after fixed charges, reached its peak in 1929, with a total of $897,000,000; averaged $35,000,000 per annum from 1931 to 1937, and amounted to a net deficit of $129,000,000 in 1938, and a net gain of $95,000,000 in 1939. The rate of return earned by the railroads on their investment in transportation property averaged 4.81 percent in 1929, 1.67 percent for the years 1931 to 1937, 1.43 percent in 1938, and 2.26 percent in 1939. The small returns during the past few years were only secured by heavy reduction in maintenance and other expenditures, some of which must be made up in the future.

Study No. 3951, made by the Interstate Commerce Commission Bureau of Statistics, showing the fluctuation in railroad freight traffic compared with production, for the years 1928 to 1938, inclusive, shows that the ratio of actual railroad tons handled to the potential railroad tons declined progressively each year, with the exception of 1934 (when the percentage was up one point), until only 78.7 percent of the potential tonnage was handled in 1938 compared with 1928.

A number of factors have caused changes in the distribution of commercial transportation among the various agencies. In the passenger field, it is the increasing use of private automobiles and the use of automobile busses on the highways; and in the freight field, it involves relocation of industry, increasing use of coal substitutes, increasing use of privately owned trucks, and increasing use of government subsidized forms of transportation.

Comparing the changes in freight ton-miles handled by three of the principal agencies of transportation in 1937 with 1926, the following percentage figures are of interest:

Steam railroads decreased 19 percent; intercity trucks increased 84 percent, and inland waterways, exclusive of Great Lakes, increased 77 percent.

Table 2 of the 1938 report shows that a total of $1,183,891,287 had been expended or authorized for the inland waterway system, comprising Mississippi–Ohio, intercoastal canals and other waterways in the United States, as of June 30, 1937. This report also shows a total of $133,564,000 additional required to complete the various projects then in course of construction.

A similar figure, reported by the chief of engineers, United States Army, shows a total of $1,309,406,300 expended or authorized for the Mississippi–Ohio, intercoastal canals and other waterways in the United States, an increase of $125,515,013 as compared with 1937. At the same time there was required a total of $135,519,825 to complete the various projects. This makes the total for June 30, 1938, $1,444,926,125, which is an increase of $127,470,838 as compared with the previous year.

These figures simply show that the federal policy of spending money in inland waterway transportation projects is continuing, and as long as this policy continues, we can expect to see an increased volume of business being diverted from the railways to the inland waterways from year to year.

I was very much interested in what Vice-President Buford said. It is up to you to go out and sell the public, the taxpayers, that they must insist that legislators stop spending this kind of money.

Vice-President Fanning: Is there any discussion on this report?

President Hastings (from the floor): This is one of the finest economic presentations that has ever been made to this Association. Following just one step further, the thought which I endeavored to present to you this morning, if you are concerned in the affairs pertaining to citizenship and to the welfare of your country, is that you need to be outspoken on these great economic questions that face us.

It is not only the question of the survival of our railroads; it is not only the matter of fairness to ourselves as railroad officers and employees and to the public in the performance of our duty to them, but it is as citizens of this country, that we need to come out into the open and not be soft-pedaling these things that are paraded before us.

If we expect to continue this country as a place in which we can live as happy and free people, we need to be outspoken in our thought and in our study, in our conclusions on these great economic questions. We might just as well face the facts and say what we have to say.

You ought to study this report in all of its phases. Carry through in your own mind the conclusions that you are bound to reach if you will analyze the figures and facts that are presented in these great expenditures for so-called public improvement. Take it home and think about it, and tell your neighbors about it because, after all, you and I as taxpayers of the country are paying for it. (Applause)

Vice-President Fanning: Is there any further discussion? If not, we will go on with the next subject.

Chairman Stout: The next subject assigned to the committee is, Effect of high speed on railway operating expenses. A second progress report relating to this assignment is included as Appendix F. Some of the complexities of the problems are pointed out. Mr. M. F. Mannion, chairman of the subcommittee, will present the report.

Mr. M. F. Mannion (Bessemer & Lake Erie): The report of this subcommittee will be found on pages 150 and 151. Under the heading "Maintenance of Way Expenses" attention is called to the increasing investment in track and other structures, together with improved operating and maintenance methods resulting in decreased maintenance costs. This makes it impossible to determine from any cost data the effect of high speeds on such costs. Also, the radically different designs of equipment being used in high speed service make present cost data worthless in determining the effects of high speed on maintenance of equipment expenses.

Under the heading "Transportation Expenses" are shown the results of two studies made in an effort to determine the effect of high speed on transportation expenses. It will be observed in both instances that high speed had very little effect on transportation expenses. It can be added that the same will hold true in all cases where the traffic does not approach the track capacity of the road. Where traffic is nearer the capacity, the effect of high speed operation will be very much more noticeable.

The report is presented as information and progress.

Vice-President Fanning: Any discussion? If not, it will be so received.

Chairman Stout: The next subject is Effect of rail lubrication on train operation. A brief, introductory report of this subject was given last year. There is included in Appendix G, a description and a statement of the results obtained from a series of tests with a dynamometer car, on the Denver & Salt Lake Railway, conducted last summer. These tests included runs before the installation of lubricators and runs after automatic lubricators had been placed.

Mr. J. A. Parant, chairman of the subcommittee, and under whose direction and supervision the experiments were made, will present the report.

(President Hastings resumed the chair.)

Mr. J. A. Parant (Boston & Maine): The application of oil or grease, either by hand or with mechanical devices, to the gage side of the high rail of curves or to the wheel flanges, has been practiced by both steam and electric railroads for a number of years. The effect of this lubrication in so far as it applies to rail abrasion has been developed in past reports of the Committee on Track. This subcommittee's assignment was to endeavor to measure the reduction in train resistance by the lubrication of curves.

On entering curves there is a temporary reduction in the drawbar pull as registered by the gage of the dynamometer car. The extent of this reduction depends on the degree of curve and on the speed. On the other hand, an increase in the drawbar pull will be registered when the temporary slack is taken up and the train is being pulled through the curve.

The committee's tests were made last June between Utah Junction, Colo., and the east portal of Moffat tunnel on the Denver & Salt Lake Railway and covered a distance of a little over 45 miles. In all, six tests were run, three before the lubricators were put in operation and three after. The lubricators were adjusted and put in service between these two series of tests and were kept in operation for 13 days, during which time approximately 200 trains passed through them. A representative train was held intact throughout the test, and the same locomotive was used for all six tests.

Briefly stated, the results of the tests indicate that rail lubricators properly located and properly functioning will reduce curve resistance approximately 50 percent and will effect an increase in the tonnage rating where the grade on curves controls the train load.

Your subcommittee is indebted to the Denver & Salt Lake Railway and its maintenance, operating and mechanical officers for their cooperation in providing the locomotives, cars, track and crew, and to the Chicago, Burlington & Quincy Railroad for the use of its dynamometer car and the valuable services of its dynamometer car engineer.

This report is offered as information.

President Hastings: Is there any discussion of this part of the report? If not, it will be received as information.

Chairman Stout: The ninth subject is Economics of railway location and operation as affected by railway electrification. Supplementary to the valuable report and compilation of data presented under this assignment last year, there is included in this year's report, as Appendix H, a further progress report of information. Professor E. E. King, chairman of the subcommittee, will submit this report.

Professor E. E. King (University of Illinois): Last year the subcommittee undertook a study of electrification of steam lines throughout the world; its report included data on electrification of lines in the United States and Canada. This year the subcommittee began to collect data on lines in other countries of the western hemisphere, Africa, Australia and New Zealand. Because of the distances and time involved, it was not possible to obtain this information in time to print it in this year's report.

Information is now at hand, however, for all lines in the western hemisphere, and it will be printed in next year's report. The committee is grateful for assistance, in this connection, to the Bureau of Foreign and Domestic Commerce of the United States government.

President Hastings: Is there any discussion of this portion of the report? Proceed, Mr. Stout.

Chairman Stout: Subject No. 10 is Compile operating data essential to establish units for making line and grade revisions to meet operating requirements. As a conclusion of the report submitted four years ago and the summary presented last year, there is now offered a final report, Appendix I, with a recommended conclusion for publication in the Manual. Mr. J. M. Farrin, chairman of the subcommittee, will present the report.

Mr. J. E. Farrin (Illinois Central): The report of Subcommittee 10, Compile Operating Data Essential to Establish Units for Making Line and Grade Revisions to Meet Operating Requirements, may be found on page 155.

Since the publication of this report, the committee has received criticisms regarding the manner in which several of the items making up the report were treated and also suggestions for the clarification of others. These were carefully considered at a meeting of the committee on February 8, and certain of the clarifications suggested have been carried out. However, as to the criticisms affecting certain substantial items in the report, the committee decided that the report as written should stand. Each one of the items has been taken up separately, but as they are all more or less inconsequential and affect only changes in wording and are designed primarily for clarification, it seems unnecessary to go through them in detail at the present time, unless the President wishes it to be done in that form.

President Hastings: Unless there is objection we will ask Mr. Farrin to proceed. He might call attention to any changes that are material.

Mr. Farrin: One suggestion that we agreed to put in was "Insurance" under item 7, page 159. Instead of reading "Taxes" it will read "Taxes and Insurance."

This report was compiled for inclusion in the Manual, and I move that it be accepted for publication.

(The motion was seconded)

Secretary Lacher: Does that include "Statement A"?

Mr. Farrin: Yes, sir.

President Hastings: We understand that the changes that the committee itself has made in the report, as a result of certain comments, do not affect the meat of the report in any way, but were solely a question of verbiage. Is that correct?

Mr. Farrin: That is correct.

President Hastings: Are you ready for the question?

Mr. C. A. Knowles (Chesapeake & Ohio): It seems to me that the report, in its determination of net cost of improvement, omits one very important factor. I refer to the item of federal income taxes. If a railway has taxable income, then in the case of retirement of property there is a deduction against that taxable income. That deduction represents real dollars, real money, real cost, and has a direct effect upon the net cost of the improvement and, as such, it seems to me should be considered in determining that net cost.

Mr. Farrin: There is nothing in the report that would prohibit any engineer in making an estimate from including the result of federal income taxes.

On page 159 under item 7, the committee decided to change "Taxes" to "Taxes and Insurance" stating that where these are factors they should be considered.

President Hastings: Is there any further discussion?

(The motion was then put to a vote and carried.)

Chairman Stout: Subject 11 is, Effects of speeds in excess of 75 miles per hour on the economics of railway location. Increased train speeds have brought a number of economic problems. The third presentation on this subject, contained in Appendix J, is a progress report and will be presented by Mr. C. W. Breed, chairman of the subcommittee.

Mr. C. W. Breed (Chicago, Burlington & Quincy): The report of the subcommittee this year consists primarily of the description of a method by which the speed performance of a motive power unit, Diesel or steam, and its cars may be shown graphically by plotting their velocity profile on the engineer's profile of one or more located lines. A comparison of the possibilities for high speed operation may be taken directly from the velocity profile.

On page 159, second paragraph, sixth line, we would like to add before sentence beginning "Comfortable riding," the words "Experience has demonstrated that," so that the sentence would read: "Experience has demonstrated that comfortable riding in passenger equipment traveling at 100 miles per hour can be provided on tangent track", striking out the word "only" and "and on curves of one degree or less."

On page 160 is shown a form for setting down data for the purpose of developing the acceleration grade percent for speeds from start to 100 m.p.h. in five-mile steps for the particular power unit and cars under study. Then follows a detailed example of the preparation of a templet for, and the necessary steps for plotting, the velocity profile.

On page 162 are directions for making a scale from which the elapsed time between any two points may be measured.

The accuracy of this method of determining the performance of a power unit, Diesel or steam, has been demonstrated on several occasions by dynamometer tests of the power under study.

The committee recommends that this report be received as information and the subject continued.

President Hastings: The report will be received as information.

Chairman Stout: Subject 12; Grades and alinement through tunnels. The second report on this subject, containing additional information and conclusions that are recommended for inclusion in the Manual of Recommended Practice, appears in Appendix K. Mr. F. N. Nye, chairman of the subcommittee, will present the report.

Mr. F. N. Nye (New York Central): The report of Subcommittee 12 is generally based upon a questionnaire sent to the chief engineers of all railroads comprising the AAR and to the chief engineers of all major roads in Canada and Mexico.

The responses to the questionnaire were very complete. The data furnished the committee have been analyzed and tabulated in the report. We wish at this time to thank these many chief engineers for their invaluable cooperation.

The principal factors to be considered in the determination of the grade and alinement through tunnels are included under the heading "Discussion."

The conclusions, set forth on page 171, were reached after studying the located characteristics of over 400 tunnels and their approaches, on more than 50 railways, giving due account to reported operating conditions through these tunnels and careful consideration to those tunnels which were described as restrictive to heavy train movements.

(Mr. Nye then read the five conclusions set forth on page 171.)

Mr. Nye: The committee recommends that these conclusions be adopted and printed in the Manual. I so move.

(The motion was seconded, put to a vote and carried.)

Chairman Stout: Our thirteenth subject, Effect of highway transportation on the economics of railway operation, is a new assignment. We report progress in study on it this year.

This completes the report of Committee 16—Economics of Railway Location and Operation.

President Hastings: Mr. Stout and members of Committee 16, I hardly know how to express the thanks of this Association. You have done a most magnificent piece of work during this past year. It was to be expected, sir. Your committee has always brought to this Association splendid contributions that add much to the knowledge of the subjects that you study. So the simplest thing is possibly the best, when we excuse you we just excuse you again with the thanks of the Association.

Discussion on Yards and Terminals

(For Report, see pp. 243–263)

(Vice-President Fanning presiding.)

Chairman Hadley Baldwin (New York Central): The first assignment to the committee is Revision of Manual, the report on which will be submitted by Mr. Lyford, the chairman of the subcommittee.

Mr. L. L. Lyford (Illinois Central): This report consists of definitions for four words which have been used recently in the Manual material, for which there are no definitions in the Glossary.

We propose the following definitions for adoption in the Manual.

(Mr. Lyford read the definitions found under Appendix A, on page 243.)

Mr. Lyford: I move that thest be adopted for printing in the Manual.

(The motion was seconded.)

Mr. S. H. Poore (Chesapeake & Ohio): In the definition of escalator, it occurs to me that it might more properly be "One manufacturer's name for a moving stairway" instead of "trade-mark." That brings to my mind a picture or some mark on a printed page that identifies.

Mr. Lyford: There is no objection to that change.

Professor W. C. Sadler (University of Michigan): I frankly hadn't read over the matter of the car retarder definition. The Germans use a method where the wheel revolves in a magnetic field. I was wondering how Mr. Lyford planned to handle that. Are you talking purely about the car retarders that are in practice in the United States, purposely avoiding the German type?

Mr. Lyford: That is correct. The definition is for the type of retarder that is used in this country.

(Mr. Lyford's motion was then put to a vote and carried, the change in the definition for Escalator having been accepted by the committee.)

Chairman Baldwin: The second assignment of the committee is: Requirements in terminal facilities for various later types of equipment. This is a very comprehensive subject, embracing a great range of functions. The committee has made extensive explorations and some digest of the situation which seems to be rather unstandardized at present, so that there is demand for the work of such a committee. The committee expects to have something definite to report at the next convention.

The next assignment is: Auxiliary yard facilities and appurtenances—wheel and truck handling equipment for coach yards. This report will be submitted by the subcommittee chairman, Mr. Mottier.

Mr. C. H. Mottier (Illinois Central): This general subject, "Auxiliary Yard Facilities and Appurtenances" embraces several facilities that the committee proposes to treat. This year we are reporting on "Wheel and Truck Handling Equipment". Next year we propose to take up other phases of this general subject.

We first deal with some general problems, calling attention to the necessity for removing wheels, and then outline the customary method by which the removal is accomplished. This involves wheel-dropping jacks, generally equipped with the "V" block which engages the axle.

Under the caption "Modern Wheel-Changing Equipment" attention is called to changes in design of equipment particularly the axle, which have been brought about by the addition of roller bearings, and the attachment of pulleys, gear housings and other connections used for air-conditioning and car lighting equipment. The difficulties encountered when the axle is engaged by the "V" block have made it very desirable to use the more modern type of drop-pit table, by which it is possible to engage the bottom of the wheels making it unnecessary to remove any of the pulleys and other gadgets from the axles.

At the bottom of page 244 and the top of 245 are indicated four characteristics which these modern drop-pit tables should have, and attention is called to the range in capacity and dimensions of the modern drop-pit table.

Under the captoin "High-Lift Portable Jacks for Wheel Changing" attention is called to certain conditions which make that type of equipment more desirable, at least from the viewpoint of certain railroads, than the modern drop-pit table. Likewise, at the bottom of page 245 are presented four desirable characteristics of the high-lift portable jack.

On the following page some general comparisons are made between drop-pit tables and electric jacks. Under certain conditions, one is more desirable than the other. But our investigation indicates that, speaking generally, the drop-pit table has a wider application and is used to a greater degree than the electric jack.

The large, modern, four-support drop-pit table which has been developed recently, largely in connection with servicing the four and six- wheel trucks of Diesel equipment is then discussed. It was our original plan to treat the servicing of Diesel equipment separately under Assignment 2 and for that reason, we did not endeavor to treat it exhaustively in this report but have considered the condition existing in some yards where it is necessary to take care of Diesel equipment and also standard conventional equipment. In that connection, reference is made to large four-support drop-pit tables, transfer tables, cranes, and other means of taking care of both Diesel and conventional equipment.

The concluding section with the caption "Auxiliary Facilities" deals principally with those facilities provided to bring in and remove wheels from the drop pits.

The report is submitted as information.

Mr. A. G. Dorland (Elgin, Joilet & Eastern): In the second paragraph on page 244 it says that the wheel-dropping jacks are usually equipped with "V" blocks. I think the new ones are generally equipped with a half-circle groove instead of the "V" block. I think it should be "V" block or a half-circle groove.

Mr. Mottier: We will be glad to make that change.

Vice-President Fanning: The report will be received as information.

Chairman Baldwin: We will now offer the report on Substitution of outlying yards and facilities for yards and other large facilities in cities where land values are high. Mr. Giles, chairman of this subcommittee, will present this report.

Mr. W. H. Giles (Missouri Pacific): A progress report on this subject was presented last year, which, after further study and consideration, has been revised and expanded, and is again offered as information with the recommendation that the subject be discontinued.

Vice-President Fanning: Is there any discussion? It will be received as information.

Chairman Baldwin: The next assignment to the committee is: Classification yards, collaborating with Committee 16—Economics of Railway Location and Operation. This subcommittee has no report this year but reports progress.

The seventh and last assignment is: Bibliography on subjects pertaining to yards and terminals appearing in current periodicals. This report appears as Appendix E, beginning on page 252 and extending to and inclusive of page 263. The committee takes occasion again to express its grateful appreciation of the one-man job that Mr. Tratman, the chairman and the committee in toto, has presented to the Association in this statement and assembly of bibliography on subjects pertaining to yards and terminals.

Vice-President Fanning: Mr. Baldwin, in the absence of Mr. Harrison, will you present the report of his subcommittee?

Chairman Baldwin: The report of the subcommittee appears in Appendix C on page 247. It has to do with certain changes in the Manual. On page 14–40, there are certain maintenance tolerances for application to railway track scales. I will read the explanatory paragraph.

(Chairman Baldwin read the last paragraph on page 247.)

Chairman Baldwin: It is not necessary to read the recommendation; you have that before you. That is the first proposition.

Vice-President Fanning: Any discussion?

Mr. Hirschthal: Does that question apply to the whole section?

Vice-President Fanning: No, just to the maintenance tolerance.

Chairman Baldwin: On page 247 is quoted the present content of the Manual and on the top of page 248 is the revised form to be substituted therefor, which does not change the intent or the purport but is solely for clarification.

Vice-President Fanning: Is there any discussion on that? Unless we find some change, we will vote on this en masse.

(Chairman Baldwin read the material appearing under page 14–40 on page 248, page 14–97 on page 248, and page 14–99 on page 249, and his motion to adopt the recommendations of the committee was seconded.)

Vice-President Fanning: Is there any discussion?

Mr. Hirschthal: Is there any reason for the rapidly increasing percentage of tolerance that occurs in the table on page 249? We start with 10 lb. and have 10 grains. When you get down to one lb. you have 2.5 grains, which is two and one-half times as much tolerance in percentage as you have at 10 lb.

Mr. E. P. Vroome (Howe Scale Company): It is much more difficult, of course, to gage your weight to 2.5 grains than to 10, so as the weight decreases in size, the tolerance obviously needs to be increased.

Mr. Hirschthal: There is no question of that. It is only a question of the increased percentage. You have two and one-half times the amount of tolerance.

Vice-President Fanning: Isn't it more a question of the actual amount rather than percentage? You are getting down to pretty fine amounts.

Mr. Hirschthal: That is true, but you do get down to one in this.

Vice-President Fanning: This is still a truck scale.

Chairman Baldwin: It seems rather insignificant.

Vice-President F. L. C. Bond (from the floor): Isn't this just a case of setting up the practice of the National Bureau of Standards?

Chairman Baldwin: Yes, at least our table is adjusted to conform to that.

(The motion was put to a vote and carried.)

Chairman Baldwin: That completes our report.

Vice-President Fanning: The Yards and Terminals Committee is excused with the thanks of the Association. (Applause)

Discussion on Wood Preservation

(For Report, see pp. 477–517)

(Vice-President Fanning presiding)

Chairman C. F. Ford (Chicago, Rock Island & Pacific): The committee has nothing to report on Subject 1, Revision of Manual.

Subject 2, Service test records for treated ties, will be found in Appendix A. This is the usual progress report on various railroads, revised to include data for 1938. The subcommittee has also included a report of ties in special test tracks on a number of railroads. This report is submitted as information.

Vice-President Fanning: If there is no discussion, it will be so received.

Chairman Ford: Subject 3, Piling used for marine construction, will be found in Appendix B. This covers the inspection of long-time test pieces of piling in the Canal Zone and other localities under observation. This report is also submitted as information.

Vice-President Fanning: Is there any discussion? If not, the report will be received as information.

Chairman Ford: On Subject 4, we have no report. Subject 5, Destruction by termites and possible ways of prevention, in Appendix C, will be presented by the chairman of this subcommittee, Dr. Hermann von Schrenk.

Dr. Hermann von Schrenk (St. Louis, Mo.): Our report this year is a progress report, found on pages 514 to 516. We are becoming rather more ambitious in putting out test tracts in connection with methods of combating these destructive creatures. You will note from this progress report that we have over 344 pieces that have been in service this year, treated with various compounds, the selection of which was determined very largely by the arguments presented by manufacturers and others. Many of them have never previously been tried.

The committee wishes to apologize to the Association for an omission in this tabulation dealing with the names of these compounds. The chairman has already been requested by one member of the subcommittee to give the actual formula for Hooker Solvent T and other compounds with trade names. We will ask that an addition be presented for printing. Some of these have names that extend over almost one line of writing. If in the mean time anybody wishes to know what Hooker Solvent T, etc. are, the chairman will be glad to advise.

In addition to the tests reported here, a number of the commercial companies who are manufacturing these compounds have made installations on a very much larger scale. In view of the fact that most of those were inserted this year, your committee did not deem it advisable to burden the report with a lengthy list.

The committee wishes to repeat its request made year after year. If anybody has any contact or experience with the activities of these termites in railway structures, please advise the committee because some of these might turn out to be extremely interesting and important. The subject is presented for information.

Vice-President Fanning: Thank you, Dr. von Schrenk.

Is there any discussion on the report?

Mr. Meyer Hirschthal (Delaware, Lackawanna & Western): I would like to ask whether the osmose treatment has been called to the attention of this committee.

Dr. von Schrenk: Yes, indeed. We are watching all of the installations which have been made with that. Of course, they are all of them very recent.

Mr. Hirschthal: The first I know of is '37.

Dr. von Schrenk: No very important results are yet obtainable.

Vice-President Fanning: Any further discussion? If not, you may go on, Mr. Ford.

Chairman Ford: The committee reports progress on subjects 6, 7 and 8. Subject 9, Present practice as to preservatives, will be found in Appendix D. The committee submits tabulation summarizing reports received from officers directly responsible for or in charge of treatment, indicating the practice as of March 1, 1938, of the railways listed. The report also includes a summary which presents numerically rather than by name, railroads using standard and other than standard preservatives. This report is submitted as information.

Vice-President Fanning: Any discussion? If not, the report will be so received.

Chairman Ford: That completes our report, Mr. Chairman.

Vice-President Fanning: The Wood Preservation committee has offered its usual fine report. It is excused with the thanks of the Association. (Applause)

Discussion on Rules and Organization

(For Report, see page 290)

(President Hastings presiding)

President Hastings: Next on our schedule is the report of the Committee on Rules and Organization, Committee 12. I will not call this committee to the platform because it does not have anything at this time to present to the Association.

The chairman of the committee, Mr. W. T. Dorrance, assistant to chief engineer of the New Haven Railroad, has asked me to direct attention to the brief statement offered by the committee on page 290 regarding the work done during the past year. The fact we do not call this committee to the platform is not indicative of any inaction on the part of the committee. It has been very active, and the members are greatly interested in the work at hand.

Considerable collaboration with the several committees of the Association is in progress and it will be necessary to continue this before Committee 12 can present any material to the Association. The committee has the thanks of the Association for the active work that it is doing. It is hoped that a profitable report and one that is very informative will be presented to the convention next year.

Discussion on Waterways and Harbors

(For Report, see pp. 172–181)

(President Hastings presiding)

Chairman G. P. Palmer (Baltimore & Ohio Chicago Terminal): The committee has no changes to recommend for revision of the Manual.

Subject 2, Breakwaters, bulkheads and jetties, has been before the committee for a number of years, and the report in Appendix A is the final report on the subject and is presented as information. Mr. Smith, the subcommittee chairman, was unable to be here and asked me to handle the report for him. The report contains three definitions for inclusion in the Manual, keeping in mind the instructions that nothing should be placed in the glossary of definitions that can be found in the dictionary. However, as the dictionary does not cover these three definitions as we use the terms, the committee thought it would be desirable to include the definitions shown at the top of page 173. The first definition for inclusion in the Manual, that for a bulkhead, is as follows:

"Bulkhead—An engineering structure to prevent sliding of natural ground or fill material into the water; the limiting wall or structure along a water front."

The committee recommends that this be included in the Manual and I so move.

(In the discussion of this motion, which was duly seconded, objections were raised to the use of the term "engineering" in these definitions on the ground that it is superfluous. However, after various suggestions were offered for the revision of the definitions, Mr. John E. Armstrong (Canadian Pacific) dircted attention to the established rule of the Association to the effect that definitions must be either accepted as presented or rejected. This point being sustained by President Hastings, Chairman Palmer withdrew the motion for the adoption of the definitions.)

Chairman Palmer: The third subject before the committee is, Warehouse piers, coal piers, car float piers and others on the Great Lakes and seacoast. This is a final report on this subject and is offered as information. Mr. Swatosh, the chairman, will present the report.

Mr. W. R. Swatosh (Erie): The final report of Subcommittee 3 is shown as Appendix B, pages 177 to 180. It covers in a descriptive manner the general features encountered in the design and construction of transfer bridges and other facilities. This report is being presented as information, with the recommendation that the assignment on Warehouse Piers, Coal Piers, Car Float Piers and Others on the Great Lakes and Seacoast be discontinued.

President Hastings: The report will be received as information. As to the discontinuance of the subject, that matter lies entirely with the Board Committee on Outline of Work. Is there any discussion of this part of the report on warehouses, coal piers and so forth?

Chairman Palmer: The next report of this committee is, Selection of type of construction of piers in various kinds of water, including materials used therein. This is a final report and is found in Appendix C. It will be presented by the subcommittee chairman, Mr. George F. Hand.

Mr. George F. Hand (New York, New Haven & Hartford): This subject was rather troublesome, and I will read the net result of our findings as expressed toward the bottom of page 180.

(Mr. Hand then read paragraph 6 on page 180)

Mr. Hand: In other words, we do not find, after an extensive questionnaire and tabulation of a large number of facts, that there is any connection between type of construction of piers and the kind of water they may be built in.

(Mr. Hand then read the first sentence of paragraph seven.)

Mr. Hand: That sums up the whole story. The report is submitted as information.

President Hastings: Is there any discussion of this portion of the report, "Selection of Type of Construction of Piers in Various Kinds of Water, Including Materials Used Therein?" If there is no discussion, it will be received as information.

Chairman Palmer: This completes the report of Committee 25—Waterways and Harbors.

President Hastings: Mr. Palmer and members of the committee, the Association thanks you for the work which you have done in the past year. The committee is excused with thanks of the Association.

Discussion on Buildings

(For Report, see pp. 183–212)

(President Hastings presiding)

Chairman L. H. Laffoley (Canadian Pacific): This year the committee was given eight subjects for consideration. We present reports on three, report progress on two, and on three we are making no report. The first subject, Revision of Manual, is in Appendix A.

In the absence of Mr. Belden, the chairman of this subcommittee, I will offer the first part of this report. The committee recommends that the first sentence in the first paragraph of Section 110, under General Conditions, in the Specifications for Railway Buildings, on Manual page 6–3, be revised to read as follows: "All work shall conform with the Federal, State or Municipal laws, ordinances or regulations governing such work." This recommendation is made merely to include the word "Federal" because some federal legislation which is now in effect relates to building codes. I move that this change be included in the Manual.

(The motion was seconded, put to a vote and carried.)

Chairman Laffoley: The committee also recommends that the present Specification for Structural Steel and Iron, as published in the Manual, Section XII under Specifications for Railway Buildings, pages 6–47 to 6–67 inclusive, be withdrawn, and a new specification be adopted to replace it.

This particular specification was deemed of sufficient importance to be considered by a joint committee made up of members of Committees 6 and 15, under the chairmanship of Mr. Judd, who will present the report.

Mr. F. R. Judd (Illinois Central): A little history might be apropos at this time. The original specifications in the Manual were the work of a joint committee of Committee 15 and Committee 6. Therefore, when the question of the revision of these specifications came up, it was considered the courteous thing to do, to invite Committee 15 to collaborate with us again in the preparation of these specifications. That was done and we have had very excellent cooperation from that committee. This joint committee has worked on these revised specifications for about three years.

The present specifications are found on pages 6–47 to 6–67, both inclusive, in the Manual. The revised specifications are found on pages 184 to 205, both inclusive.

The revised specifications were published in pamphlet form and sent out by Secretary Lacher, under date of September 2, 1939, to all members of those committees especially interested, namely: Committee 6—Buildings; 7—Wood Bridges and Trestles; 8—Masonry and 15—Iron and Steel Structures, with a request that each committee member go over these specifications and offer criticisms by correspondence.

Letters were received from quite a number of members of these committees. Approximately 50 percent of the communications advised that the revised specifications were satisfactory and offered no further comments. The remaining correspondence offered comments which were taken up at recent meeting of the joint committee.

We have had no further comments from other members since the publication of Bulletin 414. I propose to read the headings of the specifications as they are published and make no further comment unless there is a comment from the floor.

Certain of the clauses as published were revised at this last meeting of the joint committee in the light of the written comments. When I come to those particular clauses, I will read them so as to bring in the revisions.

(Mr. Judd read paragraph headings 1 to 4.)

Mr. Judd: Under 4 there is a slight change in (e). This paragraph will now read:

> "Where uniform live loads per square foot are used for the roof and floors of a building, the roof slabs, joists, beams, girders and columns supporting them and all floor slabs, joists and beams shall be designed for full dead and full live loads. In structures designed for storage purposes, floor girders, columns, piers, walls and foundations shall be designed for full dead and full live loads. In the design of all other structures, floor girders shall be designed for full dead and 85 percent of live loads and all columns, piers, walls and foundations supporting floors shall be designed for full dead load and the percentages of the live loads given in the following table:"

There is no change in the tabulation.

(Mr. Judd read paragraph headings 5 to 7.)

Mr. Judd: The specifications provide for a wind pressure of not less than 15 lb. The reason for this is that over the wide area that the AREA and the railroads operate, we have specified what we think is the allowable minimum pressure. Designers from their own observation and their own experience in the territory in which they operate may, of course, use a higher pressure per square foot in their own designs.

(Mr. Judd read paragraph heading 8.)

Mr. Meyer Hirschthal (Delaware, Lackawanna & Western): I wrote a letter commenting on this section. I don't know whether I am on safe ground, but my understanding is there is a patent on a design of composite beams. Whether that patent is still valid or whether it has been questioned, I do not know, but I thought I would call the attention of the Buildings committee to that fact.

Mr. Judd: The committee took that into consideration. In our general specifications we have a clause governing the use of patents. You will understand that this specification for structural steel is one out of some forty specifications, and it is not of itself self-contained. This specification cannot be used without the general specifications governing conditions, which is the first section of the building specifications. In the general conditions, the question of patents is covered.

Mr. Hirschthal: I understand, but my point is, if this patent is valid, I believe there should be a note in connection with Section 8 calling attention to the fact that this type of design is patented.

President Hastings: Do you want to make a motion to that effect?

Mr. Hirschthal: I would like to make a motion to the effect that, if this is found to be a patented type of design, a note should be appended to paragraph 8 indicating that such is the case.

(The motion was seconded.)

Mr. Judd: I just wonder who is going to make the investigation. It would seem to me that Mr. Hirschthal, in bringing this up, would make that investigation, to satisfy himself on whether or not he is bringing up a legitimate point.

Mr. Hirschthal: We have a general counsel for the eastern railroads and also one for the western railroads. The practice of our railroad has been, where a question of this character arose, to submit the question to the counsel.

Mr. Judd: Then it is the intention that Mr. Lacher should submit this question to the counsel?

President Hastings: That can be done. Practically every month there is a list of patents that is investigated by the counsel of the Association of American Railroads. Are you ready for the question on Mr. Hirschthal's motion that the footnote be placed below this paragraph in the specification, if found necessary?

Vice-President F. L. C. Bond (from the floor): Is it usual to do that? Wouldn't this be an exception in the Manual? As it has been said, the general specifications make provision for any patents that may be involved anywhere in the structure.

President Hastings: You are asking me a question, Mr. Bond, as if you wanted my personal viewpoint. I think it is entirely unnecessary to put the footnote at the paragraph, but the motion is before the house. You smoked out an opinion from me, and I have given it to you.

Mr. Bond: If my question was addressed to the Chair, I meant it to be addressed to the meeting.

(Mr. Hirschthal's motion was then put to a vote and lost.)

Mr. Judd: No. 9. There is no change in this except for adding a clause at the very end governing the use of beams that are resting on masonry. Therefore, it reads:

> "(a) Beams, girders and trusses shall ordinarily be designed on the basis of simple spans, whose effective length is equal to the distance between centers of gravity of the members to which they deliver their end reactions, or centers of bearing areas if on masonry."

There is a change in No. 10, which now reads:

> "Members subject to stresses produced by locomotives and cars shall be designed in accordance with the current specifications for steel railway bridges of the American Railway Engineering Association, except for restricted speeds, the impact shall be 33 percent of the live load."

No. 11; No. 12. There is a change in this paragraph, which now reads:

> "All parts of the structure, except those carrying tracks and driveways, shall be so proportioned that the unit stresses in pounds per square inch shall not exceed the following values:"

That is the only change. I don't think it is necessary to read the values. They have been published for some time. If there are no comments, we will pass to No. 13.

Mr. V. T. Boughton (Plainfield, N. J.): May I ask, as a matter of information, how do these coincide with the ASTM, very closely?

Mr. Judd: I haven't compared them with the ASTM. We have followed in the new AREA specification the stresses of the American Institute of Steel Construction.

(Mr. Judd read paragraph headings 13 to 17.)

Mr. Judd: There is a typographical error in the heading of 17. It reads: "Cross and Net Sections." It should read "Gross and Net Sections." There is a change in this, in that the last two words "Article 17" in paragraph (a) are changed to read "of this article" so you won't have to look for 17 although it is in front of you. In the criticisms offered by correspondence, it was contended that it would be clearer to use the words "of this article" and we accepted that.

There is a change in 18: "(a) No provision for transverse expansion in structures shall be made in wall bearing spans 50 ft. and under in span."

We have used the word "span" rather than "length," because it is confusing. As a rule the length of a truss is transverse to the length of a building, and it seemed to cause some confusion to use the word "length."

> "Wall bearing spans over 50 ft. and up to and including 100 ft. in span shall slide on smooth surfaces at one end. Wall bearing spans over 100 ft. in span shall have expansion rollers or rockers at one end. Expansion rollers shall be not less than 3 in. in diameter. Expansion ends shall be secured against lateral movement and all fixed ends against movement in any direction."

Paragraph (b) of 18: "Provision shall be made for longitudinal expansion of the structure." The change is "of the structure" in place of "in structures." All expansion provisions shall be figured for 100 deg. F. variation in temperature and for a coefficient of expansion of 0.0000065 per degree per unit of length. Expansion joints shall not be more than 200 ft. apart for buildings having masonry wall enclosures."

19. Connections. There is a change in (f). The last line of 19 (f) in the printed report reads: ". . . sufficient rivets to develop the stress in the filler." The revision is: ". . . secured by sufficient rivets to make the filler act as a component part of the connecting member."

(Mr. Judd read paragraph headings 20 to 22.)

Mr. Judd: Under 22 (h) there is a typographical error in the formula. It reads:

$$d = \frac{270{,}000t^3}{s} \sqrt{\frac{st}{h}}$$

The cube should be over in the radical sign and it should therefore read:

$$d = \frac{270{,}000t}{s} \sqrt[3]{\frac{st}{h}}$$

(Mr. Judd read paragraph headings 23 to 50.)

Mr. Judd: This last clause, No. 50, is an important clause in this specification which ties up with the complete section on general conditions. Under Appendix A there is a change in the heading. The present matter reads: "The following weights of materials, live loads and impacts are given as information for use in designing." We want to follow "for use in designing" with the words "except where they conflict with local building ordinances or with the known facts regarding the installation."

In the table there is a typographical error in that it shows cast iron weighing 26 lb. per cu. in., and it should be 0.26.

Under 2 "Live Loads" we are leaving out the printed matter at the head of this table because we have moved it to the heading under No. 1 of Appendix A. The two lines immediately below the heading have been removed.

(Mr. Judd then read paragraph headings 3 and 4.)

President Hastings: Mr. Radspinner, will you read your discussion?

Mr. Radspinner: "Formerly, wind damage to roofs was thought to have been due entirely to wind on the sides of a building exerting a prying action under wide, overhanging eaves. It was considered that the only force exerted by a wind moving horizontally and striking the slope of a roof, tended to push it downward, helping the dead load to keep it in place. Steeply sloping roofs are designed to resist such downward forces which are ignored for slightly sloping or flat roofs. Wind tunnel tests, however, have shown that there is another important action involved. When wind strikes a building, it is deflected upward, producing an area of low pressure over the surface of flat and slightly inclined roofs. The higher pressure inside the building then tends to lift the roof. This uplift force or 'suction' is equal to the difference in air pressures inside the building and above the roof, and is greater along the windward eaves, and on the leeward slope of steeply inclined roofs. A study of wind tunnel tests indicates that an average gross uplift of 30 lb. per sq. ft. should be considered over the entire surface of main roofs having a pitch of 20 deg. or less; an average gross uplift of 45 lb. per sq. ft. should be considered on overhanging eaves, or cornices, and on monitor roofs. The gross uplift, minus the weight of the roof construction, is the 'net' uplift which must be resisted in anchoring the roof."

It is suggested that uplift data as recommended by the American Society of Civil Engineers, be used. That quotation is from that.

President Hastings: Mr. Judd, what have you to say about that?

Mr. Judd: I think that is covered by our heading here. A great deal depends on the design of the building and how much of the building is open, and whether it is a single story building or a multiple story building. It is very difficult to cover all of the conditions. I think our heading at the beginning of Appendix A covers that situation. It says:

> "The following weights of materials, live loads, impacts and other loads are given as information and may be used for designing, except where they conflict with local building ordinances or with the known facts regarding the installation."

That should cover the condition that Mr. Radspinner has mentioned.

Mr. Hirschthal: May I suggest that the committee follow the same procedure that it used in Section 5? "Snow load shall be specified by the engineer to suit local conditions." You will escape that question and leave it to the engineer to decide. There is no question, as Mr. Judd says, that the specifications for the wind load will vary entirely with local conditions and the type of building. To insist on the 30-lb. uplift load in a protected section of Chicago or any other large city would be making a ridiculous provision that will lead to excessive design. If you modify that to read the way paragraph 5 reads, that is leave it to the engineer to select the type of wind load he desires, you will cover the ground.

Mr. Judd: If Mr. Hirschthal will make a statement as to how he wants to put that, the committee will be glad to accept it. I am speaking for the other members of the joint committee although they are not here.

Mr. Hirschthal: I suggest it read: "Wind load shall be specified by the engineer to suit local conditions, and for the type of building under consideration."

Mr. Judd: The committee will be willing to accept that.

(Mr. Judd then read paragraph headings 5 to 8.)

Mr. Judd: Then there is Appendix B which gives the allowable unit stresses for the various lengths of columns in accordance with the formulas that were passed on in paragraph 12, Unit Stresses, also Appendix C, which is a curve giving the allowable stress per square inch on columns for various ratios of l over r.

The motion of the Buildings committee is that these revised specifications be received as a revision of the Manual and substituted for the present specifications now contained therein.

(The motion was seconded.)

President Hastings: Is there any discussion?

Mr. W. G. Harding (Missouri Pacific): On the question of shop welding and field welding, you have an item here under "Fabrication": "Steel shall be welded only with the approval of the engineer." Haven't you something more definite on that?

Mr. Judd: There is no provision in the Manual for welding now. We are only revising the present structural steel specification in the Manual. A specification covering the welding of structures will be prepared by the committee which is in charge of another subject, namely, "Specification for Railway Buildings." Committee 6 considered it desirable to get this specification on structural steel out of the way first, and then to take out of it what could be used and build up on that a specification covering welding.

President Hastings: Does that take care of your point, Mr. Harding?

Mr. Harding: Yes.

(Mr. Judd's motion was then put to a vote and carried.)

Chairman Laffoley: The second subject to be reported on will be found on page 206 under Appendix B, Drinking water facilities in railway buildings. I will ask Mr. H. C. Lorenz, chairman of this subcommittee, to present this report.

Mr. H. C. Lorenz (Cleveland, Cincinnati, Chicago & St. Louis): This report includes a classification and description of drinking water facilities. There are two tables: Table 1 showing the equipment available from the manufacturers, and Table 2 showing drinking water requirements as recommended by the National Electrical Manufacturers Association. These and other pertinent data are offered as information.

President Hastings: Is there any discussion? There being no discussion, the report will be so received.

Chairman Laffoley: The third subject to be reported on will be found on page 208 under Appendix C, Drop pits, jacks and tables. This is to comply with the request that there was very little Manual material on this subject, although this has been previously reported on. I will ask Mr. Dorland, chairman of this subcommittee, to present this report.

Mr. A. G. Dorland (Elgin, Joliet & Eastern): This material relating to drop pits, jacks and tables, is recommended for inclusion in the Manual. If there is no objection, I shall refrain from reading the matter. I move that this matter, Drop pits, jacks and tables, shown on pages 208 to 212, including the four figures, be accepted for inclusion in the Manual.

President Hastings: Is there discussion?

Mr. Hirschthal: On page 209, on the subject of the area to be designed to resist wear due to blocking and heavy wheel loads, it says the surfaces may be reinforced concrete, wood blocks or asphalt blocks on a concrete base. It isn't necessary to have that wearing surface reinforced. The base may have to be reinforced but the wearing surface need not necessarily be reinforced. You can provide a real hard topping that will take any wear, without any reinforcement, if you have a solid foundation base under it.

I would suggest changing the wording to say "may be concrete, plain or reinforced, wood blocks or asphalt blocks."

Mr. Dorland: If no objection is offered by our committee, we will accept that.

(Mr. Dorland's motion was then put to a vote and carried.)

Chairman Lafolley: This concludes the material on which Committee 6 has to report for this year.

President Hastings: The Association appreciates the work you are doing, the revisions you have made in the Manual, in bringing that Manual right up to the minute, and that is the way we want to keep it. The committee is excused with the thanks of the Association.

Discussion on Roadway and Ballast

(For Report, see pp. 519–552)

(Vice-President Fanning presiding)

Chairman A. E. Botts (Chesapeake & Ohio): While tribute has already been paid collectively to the memory of the members who died during the past year, before proceeding with our committee assignment, we wish to pay further tribute to the memory of Mr. H. M. Swope of the Santa Fe who died September 13, 1939.

(Chairman Botts read the memoir appearing on page 520.)

Chairman Botts: Our first assignment is: Physical properties of earth materials, particularly

(a) Their effect upon roadbed performance.
(b) Structural bearing power.

on which we only report progress. However, this does not mean that the committee has been idle as it has made progress on this assignment.

The second assignment, Natural waterways, particularly drainage areas, water runoff, and size of openings, will be found in Appendix A and will be presented by Chairman Rose.

Mr. L. S. Rose (Erie): It is necessary to call attention to two errors which appear in the report. The first is near the bottom of page 521, in the equation which reads

$$qM = \frac{C}{M^{\frac{1}{n}}}$$

This should read:

$$qM = \frac{CM}{M^{\frac{1}{n}}}$$

The second error is in the equation in the middle of the first complete paragraph on page 522 where it reads:

$a = C \times 25.3 \ \frac{\sqrt{A}}{640}$ This should be written to indicate the square root of the quotient of $\frac{A}{640}$ and not just the square root of A, or $a = C \times 25.3 \sqrt{\frac{A}{640}}$

No material on the subject of computing runoff formulas has appeared in our Manual since the issue of 1911. The subject has been assigned several times in the past and at least two very complete reports have been made in which practically all of the better known formulas have been stated, each with its separate nomenclature and text, setting forth its limitations and most common usage. These reports are rather voluminous, and it may be for that reason that they did not reach the Manual. Our outline as it now appears in the Manual contains the subject "Formulas", and it is the feeling of the committee that the recommendations of the Association, even though they be more or less of a negative nature should appear in the Manual. It was with that idea in mind that the report was written as it appears here. It is submitted this year as information with the intention of recommending its publication in the Manual at the next convention.

Vice-President Fanning: Is there any discussion on this report? If not, it will be received as information with the understanding that it will be presented again next year for publication in the Manual.

Chairman Botts: Our third assignment Culverts, particularly vitrified clay pipe and culverts, specifications, is found in Appendix B. It will be presented by Mr. Swartout, chairman.

Mr. Wm. C. Swartout (Missouri Pacific): The report of this subcommittee, beginning on page 523, is given in full preceding the specifications for clay culvert pipe, and is presented as information with the hope that everyone will read it and make known to the chairman of the committee, the chairman of the subcommittee or the secretary of the Association, any comments, criticisms or suggestions. It is submitted as information this year with the intention of presenting it to the 1941 convention for approval and publication in the Manual.

For the benefit of those present, I would like to call attention to two errors on page 525. In the middle of line 2 at the top of the page, the expression "1.0 N" should be in parenthesis. The small "1", which applies to entire parenthesis, refers to the footnote at the bottom of the page. In paragraph 8 toward the bottom of the page, the enumerator and denominator of the fraction have been interchanged. On page 526, paragraph 12 the word "free" near the end of the line should be "freed", the intent of the specification being that that operation shall be by artificial means to assure complete dryness.

That concludes our report for this year unless someone wishes to ask some questions.

Vice-President Fanning: Any discussion on this report on clay pipe culvert specifications? If not, it will be received as information, with the understanding that it will be presented again next year for the Manual.

Chairman Botts: Our fourth assignment, Formation of the roadway, particularly settlement, shrinkage and subsidence, is in Appendix C and will be presented later by Mr. Chipman, chairman. On the fifth assignment: Roadway drainage, we report progress only.

The sixth assignment: Roadway protection, particularly slope protection against slides and rock falls, collaborating with Committee II—Signal Section, AAR, will be found in Appendix D. In the absence of Mr. Robinson, I will present this report.

As a result of the study of information on this subject obtained from various roads, states, and the U. S. Department of Agriculture, the following deletions and additions to the Manual are recommended:

(Chairman Botts then read the paragraph headings under Appendix D, pages 540 to 542, inclusive.)

Chairman Botts: I move that this be accepted as a revision of the Manual.

(The motion was seconded.)

Vice-President Fanning: Is there any discussion?

Mr. Meyer Hirschthal (Delaware, Lackawanna & Western): I want to call attention to an error. In view of the matter appearing on page 542, a change should be made on page 540. In the Proposed Form "Paving" should be followed by a period or comma, and "Cinders" should be tabulated separately because it is an independent subject, as outlined on the next page.

Chairman Botts: That is correct; we accept the suggestion.

Vice-President Fanning: Is there any further discussion on this report which is offered for revision of the Manual?

(Chairman Botts' motion was then put to a vote and carried.)

Chairman Botts: Our seventh assignment is: Tunnels, particularly lighting. This will be found in Appendix E and will be presented by Mr. Alexander, the chairman.

Mr. F. W. Alexander (Canadian Pacific): The report is based on information furnished by various roads in reply to a questionnaire. Notwithstanding the wide difference of present practice, each road reporting seemed to consider its own method the best for its particular conditions. The committee has outlined at some length the various schemes in use so that any interested person may select for himself a method that seems best suited to the particular requirements. This report is presented as information.

Vice-President Fanning: Is there any discussion? It will be so received.

Chairman Botts: The eighth assignment, Fences, particularly fence post and braces, corrosion-resisting fence wire, collaborating with appropriate subcommittee of Committee A–5 on Corrosion of Iron and Steel, ASTM, appears in Appendix F. In the absence of Mr. Jones, I will make a brief statement concerning his assignment.

This committee has been working on this particular subject for several years, and only a progress report is presented, which simply gives a brief outline of what has taken place in connection with the work being done. This is just a case of sitting and waiting for these tests to be completed. This is offered as information.

Vice-President Fanning: Any discussion? If not, it will be so received.

Chairman Botts: Our ninth assignment is, Signs, particularly close clearance sign, design of signs, specification and plans for telltales—overhead and side. On this assignment we report progress.

Our tenth assignment, Ballast, section design, will be found in Appendix G and will be presented by Mr. Kennedy, the chairman.

Mr. A. D. Kennedy (Atchison, Topeka & Santa Fe): The sections which we are offering this year are similar to those that were submitted last year and which are now in the Manual, except that these sections are for material with 20 percent crushed particles. I don't think any discussion is necessary on my part. I move that they be accepted for inclusion in the Manual.

(The motion was seconded, put to a vote and carried)

Chairman Botts: The next assignment under Ballast is. Develop relationship of ballast materials between service behavior and results obtained from Los Angeles testing machine. We report progress.

The next assignment under Ballast is: Investigate the use of asphalt in ballast. It will be found in Appendix H and will be presented by Mr. Podmore, chairman.

Mr. J. M. Podmore (New York Central): This report is shown beginning on page 545. I will read the parts of the report that seem important to bring out.

(Mr. Podmore read the paragraphs appearing on pages 545 and 552)

Mr. Podmore: Pages 546–549 show photographs of the progress of the work and the methods that were used in putting this asphalt-coated stone ballast in the track. A location plan appears on page 547 showing in hatched lines where the asphalt ballasted track is placed. This asphalt ballasted track, as you will note, crosses a highway just east of the depot, which is quite an important thoroughfare.

On page 550 is a diagram showing the force that was used to put in this work and the location of the car of stone, the mixing machine and the men. On page 551 a plan and a section show the location where the cross drains were installed, and also show the planking over part of the track. At this location there were several crosswalks that had to be taken care of. They are shown partly in the general view of the photograph at the bottom of page 549.

This experiment has been in service now about five months, going through the winter in satisfactory shape. The track has not heaved; it has kept in good line and good surface, while the track on either end of this ballasted section has heaved, particularly at the east end, east of the highway, where it was necessary to remove the heavy tie plates and bring the rail down on top of the ties. Also, at the highway each winter we used to shim the track as it would heave. This winter it was not necessary to do any shimming, while it was necessary to shim the other tracks that cross the same highway.

This experiment, I think, is the only one of its nature that has been tried on American railroads. The committee wrote to the various railroads two or three years ago, and found none that had tried a similar experiment.

I think possibly the members might be skeptical as to the use of asphalt in ballast. I know I was at first, but so far this experiment has proved quite satisfactory. It has been in use only five months, but time will tell whether it has real merits.

The report is offered as information with the recommendation that the subject be continued.

Vice-President Fanning: Is there any discussion on this interesting report? If not, it will be received as information.

Chairman Botts: With the arrival of Mr. Chipman, we will now return to assignment 4, with your permission.

Mr. Paul Chipman (Pere Marquette): The report of the subcommittee appears as Appendix C on pages 533 to 540, inclusive and relates to allowance for settlement, and to shrinkage and subsidence.

Settlement is due to two causes which are entirely distinct: Shrinkage, which depends on the characteristics of the material of which the embankment is made; and subsidence, which depends on the characteristics of the material upon which the embankment rests, although its amount may be affected by the kind of material in the embankment.

The subject of settlement has been thoroughly studied by this committee in the past. The present material in the Manual was inserted in 1921. Since that time the enormous expansion of the highway system of the United States has involved grading operations of unprecedented extent. The same cause which resulted in this expansion, namely, the substitution of internal combustion engines for animal power, has likewise brought about a revolution in grading practice.

The subject has been reviewed at this time in order to invite attention to the changed conditions which now prevail and to determine whether previous conclusions and recommendations are in any way invalidated by them.

It was formerly common practice in building embankments across swamps to place a layer of poles or logs known as "corduroy" on the surface. Many of these fills caused little trouble. Others have been a continual source of trouble and expense. The probability of settlement due to vibration, increased loads, breaking of corduroy, and drainage of swamps, combined with the fact that timber is no longer available at little or no cost, has made these methods obsolete. The problem now in making a fill across soft ground is to find how it can be brought to rest most quickly and economically on a firm foundation.

Where displacement may be expected, three general methods have been developed to secure accelerated subsidence: by explosives, by jetting, and by the removal of soft material.

The conclusions of the committee are found at the top of page 539 and are as follows:

(Mr. Chipman read the conclusions found on page 539)

Mr. Chipman: This report is presented as information, with the recommendation that the subject be continued, with a view to revising and expanding the present material in the Manual.

Vice-President Fanning: Is there any discussion? If not, it will be received as information.

Chairman Botts: The eleventh assignment of this committee is: Effect of locomotive blow-offs on track maintenance, collaborating with Committee 13–Water Service, Fire Protection and Sanitation. We report progress in study. A questionnaire has been perfected, and information will be gathered.

The twelfth assignment is: Revision of Manual, Appendix I.

(Chairman Botts read the report found under Appendix I on page 552, and his motion that the revisions under 401–C, Specifications, Sections 33 and 34, be accepted as revisions in the Manual was seconded, put to a vote and carried.)

Chairman Botts: That completes the report of the Committee on Roadway and Ballast.

Vice-President Fanning: This has been an interesting report. The committee is excused with the thanks of the Association. (Applause)

Discussion on Records and Accounts

(For Report, see pp. 449–475)

(Vice-President Fanning presiding.)

Chairman C. A. Knowles (Chesapeake & Ohio): The report on the first subject, Revision of Manual, will be given by Mr. Field, chairman of the subcommittee.

Mr. D. E. Field (Columbus & Greenville): Since most of this material has already been approved for printing in the Manual and arrangements completed therefor, I shall not read the entire report.

At the top of page 450 we have Form 1120 (Revised) Bridge Inspection Report—Masonry, Steel Bridges and Trestles which should be substituted for the present form 1120 found in the Manual on page 11–30. This is so recommended, since the revised form more adequately covers the subject.

I move the adoption of Form 1120 (Revised) for inclusion in the Manual.

(The motion was seconded, put to a vote and carried.)

Chairman Knowles: The report on the next subject: Bibliography on subjects pertaining to records and accounts, will be given by Mr. Braden, chairman of the subcommittee.

Mr. E. V. Braden (Pittsburgh, Chartiers & Youghiogheny): The report of this subcommittee appears in Appendix B.

(Mr. Braden read the first paragraph under Appendix B on page 450.)

Mr. Braden: Then follows a list of books and papers pertaining to records and accounts. The report is submitted as information.

Vice-President Fanning: Unless there is discussion, it will be so received.

Chairman Knowles: The report upon the next subject: Office and drafting room practices will be given by Mr. Teal, chairman of the subcommittee.

Mr. D. C. Teal (Chesapeake & Ohio): This report appears as Appendix C. Six topics were assigned for study, as listed in the opening paragraph.

A detailed report on topic (a) Methods of folding and punching drawings was made last year and submitted as information. The figures illustrating recommended folding methods have been revised to include information developed by further study and are again presented to the Association.

The drawing on page 452 shows a convenient method of folding valuation prints for storage in office filing cabinets. Page 453 illustrates recommended methods of folding drawings for attachment to correspondence files or for binding into special reports. At the present time there is nothing in the Manual relating to the subject.

Your committee recommends, and I move, that these drawings, together with the introductory text appearing at the top of page 452 be published in the Manual.

(The motion was seconded, put to a vote and carried.)

Mr. Teal: Assignment (b) Scales of reduction and enlargement is covered by a paragraph at the top of page 454. It states that a complete report on this subject was made last year and, after reviewing the subject matter, it has concluded that the report submitted in 1939 adequately covers the assignment. It is recommended that the subject be discontinued.

The report on (c) Width of rolls of paper and cloth begins with the second paragraph on 454. A table of widths best suited for railroad drafting room purposes is submitted as informaion, with the recommendation that the subject be discontinued.

Vice-President Fanning: Any discussion? It will be so received.

Mr. Teal: The report on (d) Sizes of drafting equipment and tools, contains a list of the drawing instruments usually owned by the draftsman and also the items ordinarily furnished by the company. General recommendations are made for guidance in the selection of new equipment. The report is presented as information, with the recommendation that the subject be continued.

Vice-President Fanning: Any discussion? It will be so received.

Mr. Teal: The committee reports progress in study on topic (e) Specifications of materials to be used for drawings and drafting and (f) Standard system for filing drawings and expects to submit reports on these subjects next year.

This concludes the report of the subcommittee.

Chairman Knowles: The next subject is Maintenance of way reports and records. In the absence of the chairman of the subcommittee, Mr. Restall, the report will be presented by Mr. Powell.

Mr. A. T. Powell (Grand Trunk Western): The report of this committee is found on page 456 under Appendix D.

(Mr. Powell read the report found under Appendix D on page 456.)

Mr. Powell: I move this chart be included in the Manual.

(The motion was seconded, put to a vote and carried.)

Chairman Knowles: The report on Construction reports and records will be given by Mr. Killough, chairman of the subcommittee.

Mr. E. M. Killough (Western Maryland): In this report, the following three subjects are discussed: Bridge Forms; Numbering of Bridges and Building Records.

Under the subject of Bridge Forms the committee has prepared forms for recording descriptive information and quantities for both railroad and overhead bridges built either at the expense of the railroad or paid for in whole or in part with public funds.

Under the second subject, Numbering of Bridges, the committee recommends a method of numbering bridges based on the mile and decimal system, with the prefix "X" for overhead bridges, and prefix letters for branch lines.

The third subject has to do with Building Records and Numbering of Buildings. Former committees have submitted reports dealing with methods for numbering buildings as printed in Vol. 37, pages 623–625 and Vol. 39, pages 683–689 of the Proceedings. The committee has reviewed the former reports and revised them for inclusion in the Manual.

The committee feels that a numbering system will prove valuable to any carrier but it is recommended that each road make a study of its particular problem and select the system best suited to its condition.

With this report on numbering buildings there is also submitted a form which is recommended for use as a register of buildings. The form appears as Exhibit 7 on page 685 of Vol. 39 of the Proceedings.

I move that the subject matter on bridge forms, numbering of bridges and buildings records be adopted and published in the Manual.

(The motion was seconded, put to a vote and carried.)

Chairman Knowles: The report upon the next subject, Valuation, will be given by Mr. Barnhart, chairman of the subcommittee.

Mr. S. H. Barnhart (Norfolk & Western): The first assignment of this subcommittee is, Résumé of Developments of the Current Year in Connection with Regulatory Bodies and the Courts. The activities of the Interstate Commerce Commission and its Bureau of Valuation in connection with valuation matters during the past year have been of a rather routine nature, so far as the railroads generally are concerned. Their forces have been about the same as for the previous year, the expenditures being also about the same.

There was some reduction in railroad expenses for valuation purposes in 1938 compared with 1937. The Bureau has had a number of valuations brought down to date in connection with the reorganization of railroads, and has spent considerable time in the valuation of pipe line properties.

On pages 466 and 467 of Bulletin 415, the subcommittee offers some comments with respect to certain court decisions in connection with valuation during the past year. Outstanding in these cases was the effort to have the courts accept "prudent investment" as a measure of value rather than the old principle enunciated in the case of Smyth v. Ames, which we have been relying upon so many years, but that effort was unsuccessful.

The second assignment to this subcommittee was: Study of Valuation Order 3 Reports and Records to Determine if Further Simplifications Are Possible. Members of this subcommittee, in connetcion with the department headed by Mr. E. H. Bunnell, vice-president of the AAR, have worked out a cataloging of those things which have been permitted in years gone by, in the way of simplification, which have been included in this report as Schedule (A) on page 469, being part of a communication given rather wide distribution by Mr. Bunnell, under date of March 20, 1939. In addition, the committee was successful in offering and having approved by the Bureau of Valuation certain other items which we believe will tend towards simplification of the work. That is included as Schedule (B) on page 470.

The next assignment is Form of Order 3 Reports in Connection With Joint Projects, Federal—Railroad. The committee had this subject last year, and it has been given further consideration this year, but because of some indecision on the part of the Bureau of Valuation as to just how these reports shall be made, that is, how the property shall be classified, the committee does not offer any recommended form at this time.

The last subject is Forms For a Record of Ballast Installations. This is another subject that has been carried over, and the committee offers nothing concrete this year, although it hopes by another year to be able to present something, if that is possible.

That concludes the report of Subcommittee 6.

Chairman Knowles: The report upon the next subject: Changes in or revisions of I. C. C. Classification of Accounts will be given by Mr. Barnes, chairman of the subcommittee.

Mr. H. D. Barnes (Chicago & North Western): In accordance with the arrangements described in the report in 1939, the committee has reviewed a considerable number of proposed accounting case rulings or orders submitted to Mr. Bunnell by the Bureau of Accounts of the Interstate Commerce Commission. These subjects are described in the first part of the report.

There have been no changes in the accounting calssifications since this committee's last report. The Bureau of Accounts, however, has released several new accounting case rulings and revised others. These are described in the latter part of the report.

While there have been no formal changes in the accounting classifications, it is apparent from the number of proposed rulings and orders, and from the number of rulings which have been released by the Bureau of Accounts during the past year, that the accounting classifications are undergoing a gradual piecemeal revision.

This report is submitted as information, with the recommendation that the subject be continued.

Vice-President Fanning: Any discussion? The report will be received as information.

Chairman Knowles: The report upon the next subject, Methods for avoiding duplication of reports and for simplifying and coordinating work under the requirements of the I .C. C. and other public authorities, will be given by the chairman of the subcommittee, Mr. Baldwin.

Mr. F. B. Baldwin (Atchison, Topeka & Santa Fe): The subcommittee's report is found on page 475. The report this year indicates that at present the chances are not good for simplification or reduction in the number of reports to the governmental authorities. The committee of the National Association of Railroad and Utilities Commissioners reported at its 1938 convention that practically all present reports are required by law and the state deparments are without legal authority to authorize the discontinuance of any of these now being made.

The committee also calls attention to the fact that the Bureau of Statistics of the Interstate Commerce Commission has secured an appropriation to study the cost of various forms of transportation, and there is a possibility that additional reporting on the part of the carriers will be required in this connection.

This report is submitted as information, with the recommendation that the subject be continued.

Chairman Knowles: The suggestion has just been made by one of the members of the Association that there is perhaps one accounting feature that might be briefly touched upon. I will ask Mr. Barnes if he won't say a word about the $500 minimum rule which is now in effect.

Mr. Barnes: While my report indicated that there had been no changes in the accounting classifications in the past year, it is true that, since the report was prepared, early in November, several accounting orders have been issued by the Bureau of Accounts which do constitute changes in the classification. Those orders will be incorporated in our report for next year.

The order referred to is one which increases the maximum expenditure for construction or replacement which can be charged to operating expenses, from $100 to $500. This increase is permissive, and only those roads that wish to adopt it need do so. The requirement is that any roads that wish to adopt a lower maximum can do so by notifying the Bureau of Accounts of that intention.

Chairman Knowles: For the coming year's work the committee has a new assignment, Records for property leased or available for lease. In these days of high income taxes and intense competition from other forms of transportation, it is only too obvious that it is incumbent upon every carrier to exact the utmost in revenue or income from all of the property which it owns, and that goal can only be reached by adequate information as to the property which it owns, both carrier and non-carrier.

That adequate information, in turn, can only be found by proper, comprehensive records. For that reason the committee feels that this is an important subject, and we would be very glad to receive any information or aid from any members of the Association who have such records already established or who have any suggestions for a proper form of record. That completes the report of the committee.

Vice-President Fanning: The Records and Accounts Committee is now excused with our thanks for the valuable work it has been carrying on for the Association. (Applause)

Discussion on Water Service, Fire Protection and Sanitation

(For Report, see pp. 213–242)

(Vice-President Fanning presiding.)

Chairman B. W. DeGeer (Great Northern): The progress report on Subject 1: Revision of Manual will be presented by the chairman of the subcommittee, Mr. E. M. Grime.

Mr. E. M. Grime (Northern Pacific): This subcommittee desires your approval this year of two minor changes in the specifications.

The first of these relates to hoops for wooden tanks. Under this heading the Manual now specifies the use of wrought iron. This material is considerably more expensive than steel, sometimes not so readily available. It is felt that the use of mild steel as used for bridges will answer every requirement. We therefore suggest the following change in the specification for tank hoops:

> "Tank hoops shall be made of steel conforming to all of the requirements for quality, strength, inspection and test as given in ASTM specifications for bridge steel A7–36."

The other change in the specification which we would like approval of is under the heading "Analysis of Hydrated Lime." Under the clause for procedure in this specification, the third sentence reads: "Dilute to the mark and shake thoroughly for approximately five minutes."

To conform with actual procedure, revise this to read:

> "Make up to the mark with 10 percent sugar solution and shake thoroughly for approximately 5 minutes."

I move the adoption of these two changes in the specifications.

(The motion was seconded.)

Mr. Hirschthal: I desire to call attention to the fact that this serial designation is A7–39. This is the latest revision of that specification.

Mr. Grime: Thank you, we will be glad to accept that correction.

(Mr. Grime's motion was then put to a vote and carried.)

Chairman DeGeer: The progress report on Subject 2: Cause of and remedy for pitting and corrosion of locomotive boiler tubes and sheets, with special reference to status of embrittlement investigations, will be presented by Mr. Bardwell in the absence of the subcommittee chairman, Mr. Coughlan.

Mr. R. C. Bardwell (Chesapeake & Ohio): The report of this subcommittee is in the nature of a progress report. The work on pitting and corrosion has progressed to such an extent that the troubles which were formerly considered serious, that is scale formation and corrosion, can be readily eliminated or materially reduced by following practices which have been demonstrated conclusively as being proper to take care of the situation.

One trouble which now appears to be bothering a number of railroads is intercrystalline cracking of boiler shells at riveted seams. In cooperation with a number of other societies, research work on this subject was started about ten years ago, and is being carried on at the College Park, Md., Experiment Station of the Bureau of Mines. The Association of American Railroads contributed $21,000 out of a total fund of about $60,000 for the conduct of this work, and it has been carried on in a very high-class manner.

The report that we present brings the available information up-to-date. It is, in a way, a resumé of the report made by Dr. W. C. Schroeder of the Bureau of Mines, before the Master Boilermakers' convention here in Chicago last fall. The final solution of this problem has not been found as yet, but the research is still going on at the Bureau of Mines under the very excellent leadership of Dr. Schroeder.

To date it has been found that this cracking is influenced by a number of different factors, of which the quality of water is only one. No common inorganic salts have been found which will stop it, but experiments with a number of organic compounds give definite promise of success. The Bureau of Mines has developed a small device which can be applied to a locomotive or test unit in the laboratory, which will demonstrate inside of 30 days whether a water will cause embrittlement with the treatment that is given for correction.

There are a large number of these units now in service on various railroads throughout the country, and it is hoped that, by continuing these observations, we will have this trouble under control as was the case with the other troubles previously considered serious. The report is presented as information.

Vice-President Fanning: Is there any discussion on the report? It will be so received.

Chairman DeGeer: Your committee has no report on Subject 3: Value of water treatment, and no report on Subject 4: Progress being made by federal or state authorities on regulations pertaining to railway sanitation.

The final report on Subject 5: Conditioning water for vapor heating boilers on Diesel powered trains will be presented by the chairman of the subcommittee, Mr. Ray McBrian.

Mr. Ray McBrian (Denver & Rio Grande Western): The report covers the conditioning of water for vapor boilers, including a description of the type of equipment used and the three principal methods of water conditioning, which are as follows: Proprietary compounds, condensate, and exchange filters, the exchange filters being a relatively new process. This is covered in detail. It also includes the cost of such type of treatment. The report is offered for information.

Vice-President Fanning: Is there any discussion? It will be so received.

Chairman DeGeer: Final report on Subject 6: New types of pipe and their application to railroad water service will be presented by the chairman of the subcommittee, Mr. A. W. Johnson.

Mr. A. W. Johnson (Atchison, Topeka & Santa Fe): The report is offered as information.

For more than 100 years cast iron pipe has been the principal distribution pipe line material in the United States. This pipe was cast vertically in pits with sand molds. Within the last 15 years horizontal, centrifugal cast pipe has come into use. Its advantages are greater density of material, higher tensile strength and lower cost; the tensile strength of cast iron in this pipe is approximately 25,000 lb. per sq. in.

Within the past several years in excess of 5,000 miles of cast iron pipe has been installed per year in the United States.

A new pipe coming into water service practice is coated and lined steel pipe which, because of its greater tensile strength, viz., about 65,000 lb. per sq. in., permits the use of a thin wall section. The common thickness of this new thin wall steel pipe is one-half that of standard weight steel pipe. This thin pipe is coated on the outside and lined on the inside ordinarily with a bituminous enamel. However, it might be said that a heavier pipe is just as much protection against corrosion as the coating and the lining and gives greater strength throughout its entire life and it costs about the same. There is some first cost advantage with steel pipe in sizes above 12 in. in diameter.

Another type of new pipe that has come into use is cement-asbestos pipe. It is made of cement and asbestos fiber. It was introduced originally in Italy and is used to a considerable extent in Europe today. It was introduced in the United States in 1926. The joint is a sleeve and two rubber rings which are pulled over the ends of the pipe by a jack or puller. The material resists tuberculation and is noncorrodible. Its low tensile strength, 4,000 lb. per sq. in., necessitates the use of greater wall thickness. There is some advantage in cement-asbestos pipe in first cost. Comparing it with cast iron pipe, the picture is something like this: If you assign 100 years to the life of cast iron pipe and 65 to that of the cement-asbestos pipe, they would balance in over all cost. At present, of course, we do not have definite information on the longevity of cement-asbestos pipe.

According to the manufacturers, about 600 miles of this new cement-asbestos pipe has been installed in the United States during the last two or three years.

Another new pipe material is copper tubing which is being used extensively for inside piping as well as outside service lines. It has a higher first cost but has considerable advantage in flexibility of use and ease of installation.

Vice-President Fanning: This report is offered as information. Is there any discussion. It will be so received.

Chairman DeGeer: The final report on Subject 7: Methods for rejuvenating deep wells will be presented by the chairman of the subcommittee, Mr. J. P. Hanley.

Mr. J. P. Hanley (Illinois Cenral): The report on Rejuvenation of deep wells gives the result of information secured by the subcommittee from railway representatives and others having experience in this class of maintenance work.

Frequently the production of water from wells decreases after varying periods of use, due to the clogging of the screen openings. In such cases, it is necessary to employ suitable methods for correction, if the useful life of the well is to be continued. The subcommittee found that mechanical agitation, back pressure by air and water, the use of dry ice, acid and explosives, and the extracting, cleaning and resetting of the well screen are the corrective methods generally used.

On page 226 the report presents a description of many reconditioning jobs, giving details of location, depth of well, methods used to recondition and the production improvement secured.

The five conclusions which appear on pages 228 and 229 summarize the conditions described. The report is submitted as information.

Vice-President Fanning: Is there any discussion? It will be so received.

Chairman DeGeer: The final report on Subject 8: Fire extinguishers—their types and uses will be presented by Mr. G. F. Metzdorf, chairman of the subcommittee.

Mr. G. F. Metzdorf (New York, Chicago & St. Louis): This report covers the general classifications of fires, to be used as an index in selecting the proper type of extinguisher. A detailed description is given of various types of extinguishers, together with illustrations and notes on the methods of operation, suitability, unit of installation and mantenance. Also included is descriptive material for use as a general guide for the distribution of units, a fire extinguisher chart and a working table. This report is submitted as information.

Vice-President Fanning: Is there any discussion on this report on fire extinguishers? It will be received as information.

Chairman DeGeer: The final report on Subject 9: Use and application of chemicals for preventing deposit in pipe lines will be presented by Mr. R. M. Stimmel, subcommittee chairman.

Mr. R. M. Stimmel (New York, Chicago & St. Louis): The report on this assignment summarizes the principal causes of incrustation of pipe lines, injectors, feedwater heaters, and so forth, and describes the use of chemicals to inhibit deposits. Two types of chemical substances are used most frequently by the railroads to relieve such troubles, tannins and molecularly dehydrated phosphates. This application of phosphates is a recent development.

Phosphates are used in amounts varying between one pound in 25,000 gal. of water and one pound in 125,000 gal. In some cases reports have been very favorable, while in others the results are unsatisfactory.

Tannin type substances have been used for several years for this purpose. The charge required varies widely, depending on the hardness of the water or the kind of tannin used, and so forth. From information obtained, it appears that the amounts required will vary between one pound in 15,000 gal. of water and one pound in 4,000 gal.

It is concluded that it is usually more economical to prevent deposits chemically than to clean or renew lines periodically. The report is submitted as information.

Vice-President Fanning: Is there any discussion? The report will be received as information.

Chairman DeGeer: This completes the report of Committee 13.

Vice-President Fanning: This committee has presented interesting information on a variety of subjects and enjoys a reputation for conscientious effort. It is excused with the thanks of the Association. (Applause)

Discussion on Clearances

(For Report, see pp. 319–321)

(President Hastings presiding)

Chairman A. R. Wilson (Pennsylvania): Since this report was printed there has been considerable correspondence among the members of the committee. In addition, the Car Construction committee, Mechanical Division, started actively in preparing a diagram of the limiting size of car to be authorized by the Association of American Railroads. Your committee recognizes the diagram covering encroachments on the general bridge diagram is an important matter, but, in view of the work of the Car Construction Committee, which we believe will materially strengthen our position when we present such a diagram, we think it wise at this time to withdraw our report and report progress only. That is the recommendation of the committee, Mr. President.

President Hastings: I expect, gentlemen, we will have to comply with the wishes of the committee.

Mr. Wilson, the Association appreciates the fact that you and your committee are dealing with a difficult subject and that you have a good many problems in connection with it that must of necessity be very thoroughly ironed out before final conclusions can be brought, and even then questions will come up that may, for the moment, seem to set aside those conclusions, but you are doing a fine job. The Association appreciates it. You are excused with the thanks of the Association. (Applause)

Discussion on Rail

(For Report, see pp. 609–637)

(Vice-President Bond presiding)

Vice-Chairman Robert Faries (Pennsylvania): We are all disappointed that Mr. Neubert was prevented by illness from being here. He has asked me to act in his place.

The committee records with regret and sorrow the loss of two members during the year. Mr. Charles W. Johns, chief engineer of the Chesapeake & Ohio Railway. Mr. Johns became a member of the American Railway Engineering Association early in 1907, and served on the Committee on Signs, Fences and Crossings, and Committee 4—Rail. We also lost Mr. A. F. Blaess. He had been a member of the Association since March, 1905. He was a member of the Track committee, Roadway committee, Committee on Economics of Railway Labor, the Rail committee and the Waterways and Harbors committee.

In presenting the report for Subcommittee 1, of which I am chairman, I would like to call attention to the Specifications for Heat Treated Carbon Steel and Alloy Steel Track Bolts, paragraph 3 (b) appearing on page 4–29 of the Manual which reads as follows:

> "The steel for the nuts shall conform to resulfurized nut stock grade of the American Society for Testing Materials specifications for commercial quality, hot-rolled bar steel, Serial Designation A–107, latest issue."

We have been advised by the chairman of Subcommittee 1, Committee A–1, Mr. E. F. Kenney, that there was a recent modification of the ASTM specification which provided for a maximum carbon of 0.25 and eliminated the minimum carbon requirement. He suggests that we add to our specification, in order to avoid a change in the Manual material, the words: "except that the minimum carbon percentage of Grade 27 shall be 0.15," which corresponds with the specification before it was recently changed.

The committee feels that this is a minor editorial revision for the purpose of preserving the Manual material as it is. I move that the reference to the Manual as quoted be changed to read:

> "The steel for the nuts shall conform to resulfurized nut stock grade of the American Society for Testing Materials specifications for commercial quality, hot rolled bar steel, Serial Designation A–107, latest issue," adding "except that the minimum carbon percentage of grade No. 27 shall be 0.15."

(The motion was seconded, put to a vote and carried.)

Vice-Chairman Faries: Subcommittee 2, of which Mr. Neubert is chairman, reports on Further research, including details of mill practice and manufacture as they affect rail quality and rail failures. This appears on pages 611 to 614, inclusive.

It covers the temperature limits for controlled cooling of rails, work toward revision of the present tentative recommended practice for controlled cooling of rails, study of the bend test as an acceptance test for rails, records of service failures of rails, batter tests of end-hardened rails—laboratory tests and field tests, miscellaneous studies of rail steel and work planned for 1940.

I will not read any of it in view of the fact that Professor Moore will discuss that in detail following the presentation of the subcommittee reports.

Subcommittee 3: General rail failure statistics for 1938. Mr. Barnes, will you present the report?

Mr. W. C. Barnes (American Railway Engineering Association): Before commenting on the general rail failure statistics, I would call your attention to a special report appearing on page 614 which gives the results obtained through the use of the all-ingot nick and break test in the AREA specifications for open hearth rails adopted last year.

Examination of the tabulated replies to the questionnaire as issued by the committee shows a material reduction in the number of X-rails as determined by the all-ingot test as compared with the former three-ingot test. This report is submitted as information.

The general rail failure statistics are on page 617. You will note from Table 1 that the five-year record of the 1933 rollings, namely, 73.5, is somewhat poorer than for the 1930 to 1932 rollings, which range from 60 to 67.4.

However, in the one, two, three and four-year service records of the rollings from 1935, '36 and '37, the failure record is very materially lower than for preceding years. So that in future reports I expect we will have a very low record for the five-year period.

It is probably too early to expect that the use of controlled cooling and Brunorized rail has shown much effect in this although as the tonnage of those rails increases in track, we may expect further improvement in the record, I believe. This is submitted merely as information.

The transverse fissure failure statistics begin on page 622. Table 1 on 623 shows the reported totals of 5,293 transverse fissure rails that failed in service in 1938 and 10,844 rails that were detected and removed from track before failure in service could occur. I believe the value of detection work as a safety measure is very evident from these figures.

The total fissure failures in track in 1938 exceeded, of course, by a large but unknown amount, the sum of the service plus the detected failures, namely 16,137. The fissure problem will continue to be critical as long as rails susceptible to fissure development will be found in track. This report is also submitted as information.

The report on Controlled Cooled and Brunorized Rail appears on page 628. Table 2 of this report shows the extent to which the controlled cooled and Brunorized rail is being put into service. The total of two types has now reached almost 2,200,000 tons.

Table 1 shows the failures that have been reported to November 27, 1939, the date of this compilation, a very good record. All failures suspected of being due to transverse fissure failures are very thoroughly investigated by Professor Moore.

The reports received between the date of this report and March 6, bringing the matter right up to date, still leave the record of controlled cooled rail free from any verified transverse fissures originating from shatter cracks. Also, no transverse fissures have been reported as occurring in any Brunorized rail which was rolled since the modification of that process on April 27, 1938. Dr. Moore will later give more specific information regarding the reported failures which he has investigated. This is submitted as information.

The remaining report on the AAR detector car is quite brief. There is nothing special of interest to add.

Vice-President Bond: The reports submitted by Mr. Barnes are submitted as information. Any discussion? They are so received.

Vice-Chairman Faries: In presenting the report for Subcommittee 1, I failed to mention a matter of information which I want to add at this time. The Tentative Specifications for Controlled Cooling of Rails provide in paragraph 1:

> "When rails are cooled in the regular way on the runways and hot beds to a temperature between 725 deg. and 1,000 deg. F., they shall be charged into the proper boxes or containers for controlled cooling."

Paragraph 3 reads: "Any rails showing a temperature thus determined below 700 deg. F. will not be accepted as controlled cooled rails."

In order to overcome this inconsistency, the committee has changed paragraph 3 to read as follows:

> "Any rails showing a temperature thus determined below 725 deg. F., will not be accepted as controlled cooled rails."

That is a matter of information only.

The report of Subcommittee 4, Cause and prevention of rail battering and methods of reconditioning rail ends, fastenings and frogs in track, will be presented by Mr. Graham, chairman.

(Mr. F. M. Graham, Pennsylvania, read the report contained under Appendix F, page 630.)

Vice-President Bond: This is a progress report, and there is a recommendation that the subject be continued. Is there any discussion?

Vice-Chairman Faries: Subcommittee 5 reports on Economic value of different sizes of rail. Mr. J. M. Farrin is chairman of the subcommittee.

Mr. J. M. Farrin (Illinois Central): The subcommittee working on this subject has completed a portion of its work and has prepared a number of graphs that show, by means of ratios, how the expenses that go to make up the cost of rail in track rate with each other. It is the hope that this year these ratios can be compared with actual, existing costs for a number of test sections that have been put into service on the Kansas City Southern Railway, covering a period of up to 10 or 12 years.

Pending the study of these tests whereby it is hoped to check the ratios expressed by the various graphs, it is thought best that no report be published.

Vice-President Bond: This progress report is submitted as information.

Vice-Chairman Faries: Subcommittee 6 reports on Continuous welding of rail. Mr. J. C. Patterson, chairman, is not present. I would like to say that this work is being carried on in a satisfactory way, and Professor Moore will have something to say about it in the discussion following our committee reports.

Subcommittee 7 on Service tests of various types of joint bars will be represented by Mr. Ray McBrian, chairman.

(Mr. Ray McBrian, Denver & Rio Grande Western, read the first paragraph under Appendix I, on page 632.)

Mr. McBrian: These measurements are observational. They include bolt tension, surface profile, wear bars, cocking tendency, and so forth. The effect of high bolt tension is also being studied in the laboratory by the rolling load machine. The various differences noted are not as yet conclusive and no definite statement can be made at this time.

This is submitted as a progress report, and it is recommended that the subject be continued.

Vice-President Bond: The report is so accepted.

Vice-Chairman Faries: In connection with the Service Tests of Various Types of Joint Bars, Dr. Talbot, in his presentation for the Committee on Stresses in Railroad Track, will give you some of the results that he has found in these particular tests.

Subcommittee 8 reports on Investigate joint bar failures and give consideration to the revision of design and specifications. Mr. C. B. Bronson is chairman.

Mr. C. B. Bronson (New York Central): Since the inception of the railroads, the weak link in the track has been the bar joining the rails together. Constant efforts have been exerted to strengthen this with ineffective results during the earlier days of railroading, in fact until within fairly recent times.

Recently much light has been shed on the problem: First, through the critical study of the Committee on Stresses in Railroad Track, under the direction of Dr. Talbot, whose laboratory and field observations, along with the efforts of others, led to modern bar design, based on a scientific study of the mechanics of joint bar action; second, through the installation of different types of bars on two roads now being followed in service by Subcommittee 7 of the Rail committee, which eventually will furnish basic data on their relative value, and which covers the whole field of what joints do in service, from the initial installation and on through their service life; and third, through bolt tension studies fostered by the Track committee, which is an interrelated and important subject.

The function of the subcommittee for which I am reporting is interwoven with all of the preceding work, and deals with joint bar failures and what remedies in design and manufacture might be instituted to overcome them.

Being a newly created committee, our first step was to make a survey of past experience with bar failures. A few roads had accurate data to submit, and indicated that failures were chiefly in older types of bars. Cracks or breaks were somewhat equally divided between those starting in the slots and those found at the top center of the bar. The percentage of failures per year to total in service was a fraction of one percent. Modern bars, such as the toeless type and others have had but a few failures in general, though two roads reported adversely and are much concerned with the situation.

Many divergent views and theories as to why bars fail have been noted and many suggestions have been received for further consideration. The vital points might be summarized as follows:

1. Decarburized outer skin or surface of the bar.
2. Improved heat treatment or composition to create a tougher and stronger bar physically.
3. Top center relief to avoid excessive stress concentration.
4. Bulged condition of the fishing area near the rail ends.
5. Elimination of sharp corners by beveling of rail ends.
6. Uniform loading by true vertical alinement or overcoming cocked condition of bars.
7. Avoidance of frozen joints and excessive bolt tensions by improved means of bolt tightening.

Now, vertical alinement and proper wrenching are strictly problems of application and installation, and something which should be impressed on all those engaged in setting up track. These are of utmost importance to successful service results, regardless of bar design, specifications or any other conditions. Beveling of rail ends, bulges or constrictions in fishing areas, as well as center relief on the top bearing of bars are receiving intensified study.

Changes in heat treatment or composition have been studied independently through the efforts of one road in cooperation with the AAR. The work is of a limited character, but at least a start has been made. The difficulty here lies in avoiding complicated processes or procedure, for in spite of what views might be held, joint bar manufacture is a large scale commercial operation and increased cost of the product must be borne in mind and avoided, if possible.

Relative to the decarburized condition, the bars are surrounded by an outer zone of soft metal with low physical values and carrying capacity. This is a condition inherent in all rolled steel products and practically impossible to avoid. Cooperative studies were made during the year with two manufacturers to see what steps might be taken to control or minimize its depth or extent, realizing that this cannot be completely or effectively eradicated. Valuable data were obtained from these initial studies.

Further interesting sidelights are being accumulated through the unique studies of the Denver & Rio Grande Western using photo-elastic methods on bakelite joint bar models which furnish clues of the stress concentrations and distribution under loaded conditions. The accumulated evidence may be an important aid in correcting the designs, and providing relief at zones of high stress.

While the subcommittee has nothing of a definite nature to recommend as to design and specification, this brief outline will serve to show the number of interrelated problems involved, and the efforts being made by the various committees and subcommittees and through independent sources to consider all phases of this important subject.

To avoid criticism, it should be stated that the assignments of work are purely those related to track where rails are coupled together with joint bars, and do not cover continuous rail joined by such permanent means as the various types of welding. The subcommittee will welcome information covering independent studies by individuals or railroads which might be of further aid in studying these problems.

This report is submitted as a progress report.

Vice-President Bond: You have heard a very interesting discussion on the subject, and it is accepted as such.

Vice-Chairman Faries: Professor Moore, may we now ask you to describe and discuss the work you are doing for the Rail committee?

(The substance of Professor Moore's remarks is presented in the Sixth Progress Report of the Joint Investigation of Fissures in Railroad Rails, page 673, and the Second Progress Report—Joint Investigation of Continuous Welded Rail, page 737.)

Vice-Chairman Faries: This concludes the report of the Rail committee.

Vice-President Bond: The Rail committee, having submitted the usual excellent report, is excused with the thanks of the Association.

Discussion on Masonry

(For Report, see pp. 351–406)

(Vice-President Bond presiding.)

Chairman J. F. Leonard (Pennsylvania): The first subject is Revision of Manual, Appendix A. I will ask Mr. Boyd, chairman of this subcommittee, to present the report.

Mr. G. E. Boyd (Railway Age): The recommendations for revision of the Manual are largely editorial. One or two changes are suggested to keep the specifications of this Association in line with the specifications of the American Society For Testing Materials, in the preparation of which we are represented through certain members of the Masonry Committee.

The first revision relating to fineness and compressive strength of high-early-strength Portland cement, will be found on page 352. The entire specification for fineness has been deleted from the cement specifications because of finder grinding. The proposed form follows. I move the deletion and insertion of the proposed material as shown on page 352.

(The motion was seconded, put to vote and carried.)

Mr. Boyd: The committee also recommends the deletion of the heading "Specifications for Making Pre-Molded Concrete Piles" and the substitution of a heading which will use the term "Precast" instead of "Pre-Molded." There are two specifications, both of which carry the same implication.

I move the adoption of the proposed recommendation which will be found at the bottom of page 352 and the top of 353.

(The motion was seconded, put to a vote and carried.)

Mr. Boyd: The next revision is also purely editorial. We recommend the deletion of the second paragraph under Article II of the Specifications for Pile Foundations, page 8–117 of the Manual, and the substitution of a new form which is shown at the top of page 353. I move the revision as shown.

(The motion was seconded, put to a vote and carried.)

Mr. Boyd: That concludes the report of the subcommittee.

Chairman Leonard: Assignment 2 is entitled: Specifications and principles of design of plain and reinforced concrete for use in railway bridges, buildings and culverts, collaborating with Committees 1—Roadway and Ballast, 5—Track, 6—Buildings, 7—Wood Bridges and Trestles, 13—Water Service, Fire Protection and Sanitation, and 15—Iron and Steel Structures. This assignment in detail consists of (a) Composite columns and pipe columns, work on which has been progressed through the Joint Committee on Concrete and Reinforced Concrete, and is now awaiting the result of a ballot on its report.

(b) Rigid frame bridges as related to multiple spans. As a part of the general assignment, rigid frame bridges, the report on box abutments is presented as information.

(c) Concrete bridge deck slabs of the non-ballast type, collaborating with Committee 5—Track. A report of progress is presented as information. The body of the report is shown in Appendix B. Mr. Laird, who is chairman of the subcommittee, finds that he has a cold and is unable to speak. Mr. Dayett will present this report.

Mr. G. H. Dayett (Baltimore & Ohio): The committee presents as information a discussion on box abutments, including a drawing of a typical box abutment on page 354, and photographs of a similar structure on page 355. In its study of concrete bridge deck slabs of the non-ballast type, the committee sent a questionnaire to a number of railroad companies, together with the group of illustrations of various types shown on pages 358 to 363. A tabulation of the replies to that questionnaire is included adjacent to page 356, while a summary of replies and the conclusions of the committee are given on page 357.

Vice-President Bond: This report is accepted as presented, as information.

Chairman Leonard: The next assignment, No. 3, is Progress in the science and art of concrete manufacture. There are two subjects under this assignment: (a) Needed adjustments in field practice to use present day cements to best advantage, on which progress is reported, and (b) The Autoclave test, information on which is presented in Appendix C. Mr. Walter, chairman of the subcommittee, will present this report.

Mr. L. W. Walter (Erie): This report furnishes an abbreviated history of the development of the autoclave test, a discussion of the factors upon which conclusions are drawn as to its significance, and the reasons why heretofore progress in the development of standards, both standard method of test and standard specification requirements, has been slow.

We have included in the report a Proposed Method of Test for Autoclave Expansion of Portland Cement as published in the ASTM Proceedings of 1938, Vol. 38. This proposed method of test was presented by Committee C–1 in 1938 as information. In 1939, Committee C–1 recommended it be advanced as a Tentative Standard Method of Test. It failed of adoption by the society, I think largely for reasons given in the next to the last paragraph on page 365.

(Mr. Walter then read the fifth and sixth paragraphs on page 365.)

Mr. Walter: Since the preparation of this report there have been developments in Committee C–1 as a whole and in a subcommittee, which have a bearing on this statement. This relates, of course, to both the significance of the test and to the previous lack of agreement on a suitable limit for the maximum allowable expansion in the autoclave test.

Committee C–1 has seen fit to constitute a subcommittee of ten men, none of whom is a representative of producing interests. That subcommittee concluded its studies and deliberations and submitted to Committee C–1, in December, 1939, specifications for five types of Portland cement. This subcommittee's report was referred to an enlarged subcommittee, a reviewing subcommittee, so to speak, whose membership is made up of representatives of producing interests, consuming interests and of general interests. This enlarged subcommittee has reported to Committee C–1, and its recommendations will be acted upon at a meeting of Committee C–1 to be held in Washington next week.

Now, to bring out more clearly the difference of opinion which has existed as to whether the test should be a quantitative or a qualitative test, I would like to read from a report of the first subcommittee of ten as published in the ASTM January bulletin.

> The subcommittee was divided quite sharply on the question of autoclave expansion, a number of members feeling that soundness should be controlled through the use of an autoclave test on the pat rather than by means of a quantitative test on a 10-in. neat cement bar. This group feels that sufficient data are not available to justify the use of a quantitative test limit of less than one percent expansion and that until such data become available, a qualitative pat test should be used. The group favoring the quantitative test feels that even though definite information correlating autoclave expansion of less than one percent with service behavior may not exist at present, the use of values of the order of 0.5 percent or less is desirable in order to insure against the possibility of delayed expansion. They point out, furthermore, that some evidence exists which indicates that, in regions where this trouble has been experienced, cements which have the best service records are those which now show very low autoclave expansions. The consensus of the meeting of November 30 was that quantitative limits of 0.5 percent expansion should be included for Types II and III, with 0.25 percent for types IV and V.

When this report as submitted to Committee C–1 was considered by the reviewing subcommittee, the latter offered specifications somewhat modified, in which it recommended that the maximum allowable expansion in the autoclave test be not more than 0.5 percent for each of the five types of cement.

The committee further recommended that the method of test as reported by Committee C–1 in 1939 be adopted; that being the same wording as appears in our subcommittee report beginning on page 366, as copied from the 1938 Proceedings of the ASTM.

This report is submitted as information. I think it is the wish of the Masonry committee that the assignment be discontinued.

Vice-President Bond: The report is accepted as information. The discontinuance or the continuance of the assignment will be dealt with in due course by the Committee on Outline of Work.

Chairman Leonard: We are particularly fortunate in the fact that Mr. Walter, who is chairman of this committee and has just presented his report, happens to be secretary of Committee C–1 of the ASTM, although he was too modest to say so.

The next assignment of the committee is that of maintaining contact with the Joint Committee on Concrete and Reinforced Concrete. Mr. Hirschthal, who is chairman of the AREA representation on the Joint Committee, will present the report.

Mr. Meyer Hirschthal (Deleware, Lackawanna & Western): I am pleased to be able to state that the final report of the joint committee will be turned over to the printer next month so that the publication will take place before the June meeting of the American Society for Testing Materials. The continuation of this committee will depend on the reception of the final report by the member bodies that constitute this committee.

The criticisms and suggestions that had been presented between the issuance of the progress report and the final report, were given thorough consideration, and care was taken not to turn any criticism or suggestion down completely. However, some matters had to be compromised, and I suppose there will be criticism from two parts of the critical bodies who would want the midway position eliminiated from the specifications. There really were only two points on which any differences occurred. One is the moot question of waterproofing, which is dividing the engineering profession quite thoroughly throughout the country, and the other is that of moment coefficients in frames. The Joint Committee handled those as best they could, and the product will appear in the final report.

Vice-President Bond: The presentation is accepted as a progress report.

Chairman Leonard: The next assignment is 5: Specifications for foundations, including excavation, cofferdam, piling, etc. I will ask Professor Vawter, who is chairman of this subcommittee, to present this report.

Professor Jamison Vawter (University of Illinois): The report of the subcommittee on foundations is given in Appendix D on pages 369 to 372.

(Professor Vawter read the first paragraph under Appendix D on page 369.)

Professor Vawter: There have been a few minor revisions since publication last year. In a few cases it is merely a matter of editing in changing the term "section" to "article." It will not be necessary to bring each of those to your attention. I will read the paragraph numbers and headings, calling attention to any other changes that have been made, and at each paragraph I will pause for any discussion.

(Professor Vawter read the topic and paragraph heading at the bottom of page 369.)

Professor Vawter: The term "pre-molded" has been changed to "precast" under "a" to conform to the change made in the Manual in Mr. Boyd's report.

In (b) the words "or not" have been added to the last sentence of the second paragraph, making it read: "The pile may be pointed or not as the Engineer directs."

(Professor Vawter read paragraph headings on page 370 and the top of page 371.)

Professor Vawter: Under (a) of H–Sections, in the second sentence the words "in the web or flange" have been added, making the sentence read: "The minimum thickness of metal in the web or flange shall be ⅜ in."

The third sentence: "The ratio of the flange width to depth of section shall not be less than 85 percent" has been added.

Under "c" the wording at the beginning of the first sentence has been rearranged, and the words "as practically as possible" and "with at least 50 percent of the pile top in contact with the bearing cap" have been added, making the sentence now read: "Where steel bearing plates are required they shall be suitably fastened to the top of the piles so as to avoid displacement and to provide as practically as possible an even bearing on the pile with at least 50 percent of the pile top in contact with the bearing cap." That is the only change under (c).

In (d) Protective Encasement, the second paragraph has been added as follows:

> "Structural steel piles shall not be used through cinder or ash fill or other active rust inducing material without adequate provision for the protection of such piles, unless laboratory tests of these materials prove the material to be practically free of inorganic acids."

(Professor Vawter read the paragraph headings on the balance of page 371 and down to paragraph 5 under VII Driving on page 372.)

Professor Vawter: Under 5 the words "or driven to refusal" have been added at the end of the first paragraph, and the second paragraph, reading "The number of jets and size of nozzle and the volume and pressure of water shall be determined by the Engineer," has been added.

(Professor Vawter read the balance of the paragraph headings on page 372.)

Professor Vawter: I move that Articles VI, VII and VIII of the Specifications for Pile Foundations be adopted for inclusion in the Manual.

(The motion was seconded, put to a vote and carried.)

Chairman Leonard: The next assignment, No. 6, is Methods and practices of lining and relining tunnels. I will ask Mr. Pyle to present this report which appears as Appendix E.

Mr. I. L. Pyle (Chesapeake & Ohio): The report of this committee is shown on page 373. The first paragraph gives the scope; and, following this, are suggested specifications and materials, consisting of brick, mortar, cement, lime, sand and water; then follows design, giving the interior dimensions. This is followed on the next three pages, 374, 375 and 376, by diagrams showing the tunnel sections proposed for use with this type of lining; then follows specifications for floor and ballast walls, foundation for side walls, side walls and arches, drainage openings and refuge niches.

These specifications are submitted as information, with the object of presenting them later for inclusion in the Manual. The committee requests comments from members of this Association and any criticism that you see fit to make.

Vice-President Bond: The report is presented as information and the chairman of the subcommittee is requesting your comments with the object of clarifying any point that may be open to discussion, before recommending it for adoption at the next session.

Mr. Pyle: We shall be glad to have written comments during the year.

Vice-President Bond: If there is no further discussion, the report will be received as information, with the invitation of the committee chairman for written comments on the submission.

Chairman Leonard: The next assignment is: Review specifications for overhead highway bridges of the American Association of State Highway Officials, in so far as they relate to masonry, conferring with that association, and Committee 15—Iron and Steel Structures. Your chairman has to report no progress, nor contact with the American Association of State Highway Officials, except that three attempts to obtain a meeting were unsuccessful.

The next assignment is that of Rating of reinforced concrete bridges, Appendix F, which will be presented by Mr. Robinson, chairman of the subcommittee.

Mr. G. E. Robinson (Cleveland, Cincinnati, Chicago & St. Louis): This report is found at the top of page 378 and, as it is very short, I will read it.

(Mr. Robinson read the report found under Appendix F on page 378.)

Mr. Robinson: That last paragraph was inserted with the thought that at some future time we may be prepared to offer rating rules, and the first requirement is a good record of what was put into the structure, and how.

The committee recommends that the subject be discontinued for the present.

Vice-President Bond: The report is accepted as information.

Chairman Leonard: Assignment 9: Progress in cement manufacture and testing. At the time of the presentation of the Masonry committee report last year, inquiry was made from the floor as to availibility of current information which it was felt railroad engineers needed on the subject of cement. As a matter of fact, your committee recognized that problem and had already asked for such an assignment.

We are particularly indebted to Mr. Marsh, chairman of this subcommittee, who will present this report. I am sure that all of you who are interested in this subject will find much of value in the information which he has accumulated during the past year at an enormous expenditure of time and effort.

Mr. C. P. Marsh (New York Central): There is very little I think that need be said about this report. The subcommittee has tried to present in a somewhat brief and clear manner what is a very complicated subject. The subcommittee hopes that it may be found of value to those who are interested. There are three corrections that I would like to call attention to, that we think should be made.

On page 381, in the sixth paragraph, the fifth line, the word "space" got introduced in some manner or other and should be deleted. On page 384, at the bottom of the fourth paragraph, just preceding the heading "Blended Cements" the line reads: "one percent provided that such additions have been specifically approved by its Committee C1 on Cement." That statement is not quite correct, and it should be revised to read: "one percent provided that such materials have been shown not to be harmful by its Committee C1 on Cement." In other words, Committee C1 does not approve the use of any of these additions.

On page 391, in the second paragraph under "Chemical Tests" the last sentence should read: "In the Standard Specifications for Portland Cement there are and have been for many years past limits placed upon the following chemical compounds."

The report is presented as information.

Vice-President Bond: This is a very valuable and comprehensive report and is accepted as presented, for information.

Chairman Leonard: The next assignment is that of specifications for concrete culvert pipe. Recommended specifications for the placement of concrete culvert pipe are presented as information in Appendix H. Mr. Theodore Doll, who is chairman of this subcommittee, was unable at the last moment to be present, and since it is presented only as information, I will cover the headlines briefly.

(Chairman Leonard read the paragraph headings under Appendix H.)

Chairman Leonard: This is presented as information.

Vice-President Bond: And so received.

Chairman Leonard: The next subject is: Bibliography and review of current engineering literature pertaining to railroad masonry work. This committee worked very diligently during the year and produced a fund of information which is of value to Committee 8, but we found that the material has not been coordinated in form for presentation as a committee report at this time.

The next subject 12, is that of pressure grouting, which is presented in Appendix I as information. Mr. Ray, who was chairman of this committee, is unable to be present, and I am asking Mr. Coburn to present this report.

Mr. Maurice Coburn (Pennsylvania): During the last few years there has been a great widening in development in the art of grouting. We were asked to gather some information as to developments in this art. The committee has gathered this information from various sources and presents it as information. I don't think it is necessary to go into any further detail.

Vice-President Bond: This is quite a lengthy and carefully prepared report, and we are very much obliged to the committee for the presentation.

Chairman Leonard: The next assigned subject is that of specifications for concrete and reinforced concrete railroad bridges and other structures, which is a very substantial undertaking. We report definite progress during the past year, but the preparation of this report has involved so much work, we are unable at this time to present anything for your information.

The next and last subject is that of specifications for test borings, collaborating with Committee 1—Roadway and Ballast. We have no report other than progress to make at the present time, but it is our expectation to have a report on this subject a year from now.

That completes the report of Committee 8.

Vice-President Bond: The committee has presented a very comprehensive report on a very vast subject, and it is to be complimented on its presentation. It is excused with the thanks of the Association (Applause).

Discussion on Maintenance of Way Work Equipment

(For Report, see pp. 265–289)

(Vice-President Fanning presiding.)

Chairman G. R. Westcott (Missouri Pacific): Committee 27 really had 14 subjects assigned to it, although they are numbered only to 13. On a number of these we are reporting progress in study only, as I will now indicate.

1. Revision of Manual. We have no stated report on this subject. There is, however, some Manual material that comes up in connection with another subject, on which a report will be made.

3. Lubrication of roadway machines. We found that was a much more difficult matter in a practical way than one might think at first glance.

6. Methods of keeping data on work equipment. We made a report on this last year, and this year have made some progress but are not ready to complete the work.

7. Pneumatic-tired tractor equipment. This, also, we have well under way for a report next year. The same is true of No. 9, Track welding equipment, subdivision (b) covering electric arc welding.

On No. 10, Railway owned automotive equipment, on which we made a report last year, we are postponing the completion of the report until next year.

On No. 11, Off-track ditchers, the report is under way but not complete. Progress is also being made on No. 13, Safety devices for work equipment.

On certain other subjects we are making a partial report this year, with the recommendation that the subject be continued for further study. The first of these is a subject that we have had on the docket for several years, namely, the standardization of motor car parts and accessories. Mr. R. K. Johnson will present the report.

Mr. R. K. Johnson (Chesapeake & Ohio): This subcommittee report is found on page 266, Appendix A.

(Mr. Johnson read paragraphs 1 and 2 on page 266.)

Mr. Johnson: Your committee recommends that Fig. 2708 be adopted as recommended practice and printed in the Manual. I so move.

(Vice-President Bond assumed the chair.)

(The motion was seconded, put to a vote and carried. Mr. Johnson then read the balance of the report down to "Recommendation".)

Mr. Johnson: The committee recommends that paragraph 10. Differential axles be adopted as recommended practice and printed in the Manual. I so move.

(The motion was seconded, put to a vote and carried.)

Mr. Johnson: The committee also recommends that the assignment be continued.

Chairman Westcott: We also make a partial report on the subject: Self-contained direct-blow gasoline tampers. I will call on Mr. Mills, a member of the subcommittee, to make the report on this subject.

Mr. E. H. Mills (New York Central): Section 4 of this report is mentioned briefly in Appendix B. This device was covered by a full report submitted to the Association in 1938, at which time there was only one make on the market.

The economy and usefulness of this tool and its wide range of application to purposes in addition to tamping ties, has led other manufacturers to explore this field, with the result that at least two more makes have been built and put through field tests. One of these is being shown this year and offers novel features of design, but has not been in use long enough to permit a full report at this time. This particular type of tool is in its early stages of development and will undoubtedly progress at a rapid rate. We present this as information and recommend that the subject be continued.

Vice-President Bond: As I understand it, these devices have not yet reached a commercial stage and you are withholding reports on them?

Mr. Mills. The last two.

Vice-President Bond: The report is so received.

Chairman Westcott: There might be a misunderstanding in the Vice-President's last question. One of these machines is on the market, I believe, but we did not have sufficient information to make a complete analysis of it, as we did of the first one that came out a year or so ago. We also understand that there are certain changes now in progress in the design of the machine. We thought, therefore, it was best not to attempt a detailed description of it.

For two or three years, perhaps more than that, we have had before this committee the subject of oxy-acetylene welding equipment. This is Subject 9, section (a), Track welding equipment, oxy-acetylene welding. I am going to ask Mr. Morgan, who is a member of the subcommittee, to present the report on the subject.

Mr. C. E. Morgan (Chicago, Milwaukee, St. Paul & Pacific): The report begins near the bottom of page 277 and it extends over several pages. We wish to call attention to the fact that it explains certain details that are of extreme importance and interest to members in welding work. They do not represent merely pages of reading, but technical information that is worth while.

A brief introduction is given, describing the early history or origin of the gas welding work, followed by illustrations on page 278 of the three kinds of flame. There is an explanation of each one. A paragraph is devoted to the scope of maintenance of way welding.

The welding materials are then described in detail with explanations concerning the containers in which both oxygen and acetylene are handled. Next is the material in the welding rods themselves, covered at the bottom of page 280. We then turn to welding equipment and tools. We all know that things can happen when tools are misused or abused. Proper care should be given to welding equipment. For that reason we have detailed carefully descriptions and cuts illustrating the welding torches, showing the medium-pressure and also the low-pressure injector type at the bottom of page 281.

Taking up, then, the tips which can be used with welding torches, you will find descriptions and illustrations of the two-flame tip on page 282 and the three-flame tip on 283.

The regulators used in connection with this work are described carefully and a type illustrated to clarify. Reference is also made to the fact that two-stage regulators are available and for what purposes. Manifolds are discussed at length, also the hose.

I want to call to the particular attention of those who are engaged in welding work, the information under the paragraph headed "Setting Up Outfit, Preliminary to Welding" on page 285. You will note that these items are numbered in sequence. This is given, extending over to page 286, followed by a description of the acetylene and the handling of the acetylene cylinders. Then comes a paragraph on taking down the outfit after you are through welding. This is not merely a reversal of the processes which were gone through in making the start or in setting up the outfit. The sequence described here is really important and must be followed.

At the top of page 287 is a paragraph "Precautions to be Observed." In that we stress the fact that all work should be done in accordance with "Safe Practices for Installation and Operation of Oxy-Acetylene Welding and Cutting Equipment" which is published by the International Acetylene Association. There is an addition to be added there, reading: "and the regulations of the National Board of Fire Underwriters for the installation and operation of gas systems for welding and cutting."

This report is presented as information, with the recommendation that the subject be continued.

Vice-President Bond: The subcommittee has made a valuable contribution to our literature on the subject. This will be accepted as information.

Mr. W. A. Radspinner (Chesapeake & Ohio): I would like to say something about the operation of the National Board of Fire Underwriters' regulations. The committee which prepares these regulations is not composed of insurance men, as the popular opinion seems to be, but is made up of representatives of the American Compressed Gas Association, the American Gas Association, the Bureau of Explosives, the American Standards Association, and I happen to be the representative of the Fire Prevention and Insurance Section of the AAR on that committee.

The regulations put out by that committee automatically become the law in about six states, and are used in the same manner as other national codes. There seems to be no question about adopting the National Electrical Code. The state laws have even been amended so they can adopt it by reference, without printing the entire code. The laws or codes do not say that you have to follow the regulations of the General Electric Company or the Edison Company or the Westinghouse Company. They say "the National Electrical Code." The National Electrical Code is prepared by a committee similar to the committee that prepares the regulations on gas.

I thank the chairman for including that addition in his regulation because the regulations of the National Board of Fire Underwriters do take precedence over individual regulations set up by individual manufacturers' associations, such as the International Acetylene Association, which has done a very fine job in their own regulations and have taken a great deal of pains to see that the information they have gathered is put out to the men who actually use these tools. I want to bring out the fact that the regulations of the National Board of Fire Underwriters really come first, and they are not prepared simply to protect your insurance. They are for safety to both life and property the same as these other regulations.

Mr. C. H. R. Howe (Chesapeake & Ohio): I would like to add just a word of explanation in connection with the two different codes that have been mentioned. The reason the committee did not include those regulations is that they comprise a rather extensive bulletin as prepared by either one. They are almost identical in their composition, and they are readily available as now printed, for anybody who wants to secure them. The committee did not feel that it should put the Association to the expense of reproducing something that was already in existence, and free to anyone for the asking.

Vice-President Bond: I think that explanation is satisfactory to the Association.

Chairman Westcott: Assignment 5 to this committee is the subject of concrete vibrators. The chairman of the subcommittee, Mr. Rothe of the Pennsylvania, is not here today, and I am asking Mr. George E. Boyd, who is a member of the subcommittee, to present the report.

Mr. G. E. Boyd (Railway Age): This report will be found on page 268 in Appendix C. It covers the equipment available for vibrating concrete. The advantages and disadvantages of vibration in concrete placement have been discussed by the Masonry committee in its report which will be found in Vol. 35 and Vol. 38 of the Proceedings of this Association.

Special attention is called in the report to the importance of the frequency of vibration, to the relative effect of oscillating and rotary vibrations, to the centrifugal force exerted at various frequencies, and to the importance of choosing the type of power suited to local conditions.

This report is submitted as information.

Vice-President Bond: Any discussion? If not, the report will be so received.

Chairman Westcott: Assignment 8 is the subject of Sand Blasting Equipment. Mr. R. P. Winton a member of the subcommittee, will present the report.

Mr. R. P. Winton (Norfolk & Western): The report of the subcommittee on Sand Blasting Equipment is shown on page 271. Pneumatic sand blasting equipment suitable for maintenance of way work can be divided into two groups, according to the method used in propelling the abrasive against the work.

The first group can be designated as direct pressure machines, the abrasive substance being blown from a container through a hose and nozzle by compressed air. This type of machine is described on page 271 under the heading "Direct Pneumatic Pressure."

The second group are suction machines. In these a gun is used having a discharge nozzle, behind which there is a chamber with connections for sand hose and air hose. When the air is turned on, a partial vacuum is created within the chamber, and the abrasive is drawn from its container, combining with the air and passing out through the nozzle. This type of machine is described under the heading "Suction" on page 271.

On page 273 is a discussion of the pressures and amount of air required for operating various types of sand blasting outfits.

On the bottom of page 273 is a discussion of nozzles. The earlier nozzles were made of white iron. The rapid wear begins to reduce operating efficiency almost from the first moment of their use. This situation prompted research that led to the development of boron carbide and cast tungsten liners for steel nozzles and the manufacture of nozzles of special manganese alloy steel.

On page 274 is a discussion of the performance of various types of nozzles after they have been worn.

On page 275 is a discussion of abrasives. For maintenance of way work sand is usually used, because it is not possible to reclaim it. Steel abrasives are available, which are much more efficient than sand in some types of work but are only suitable for use where they can be reclaimed, on account of their high cost.

At the bottom of page 276 is a discussion of sandblast hose. This report is submitted as information.

Vice-President Bond: Any discussion? If not, the report will be so received.

Chairman Westcott: The last subject on our assignment is No. 12, a discussion of rail loaders and unloaders. Mr. T. M. Pittman will present the report.

Mr. T. M. Pittman (Illinois Central): This report will be found on page 287. It gives, in brief, a general discussion of the rail loaders and unloaders that are now in use, and some suggestions as to features that should be incorporated in machines designed for handling rail.

This is followed by a comparison of the advantages and disadvantages of on-track and off-track machines, with the conclusion that machines that can be used only for loading and unloading rail are not economical. When purchasing new machines, consideration should be given to the adaptability of the machine to laying rail and other classes of work. The greater development and use of off-track machines will prove economical.

The committee presents this report as information and recommends that the subject be discontinued.

Vice-President Bond: Any discussion on the report as presented? If not, it will be accepted as information.

Chairman Westcott: This concludes the report of Committee 27.

Vice-President Bond: The committee is excused with the thanks of the Association for a very valuable report. (Applause)

Discussion on Waterproofing of Railway Structures

(For Report, see pp. 445–448)

(President Hastings presiding.)

Chairman J. A. Lahmer (Missouri Pacific): The first item under Revision of the Manual, is to change the rate of elongation per minute specified for the ductility test at 40 deg. F. of asphalt for saturant and mopping above ground, which is item (g) in Section 202 of the Manual. The rate of change is from 1 cm. to ¼ cm. a minute. The revised portion would read:

> "Ductility at 40 deg. F. (4 deg. C.): elongation at rate of ¼ cm. per minute—not less than 4 cm."

This was brought about because there has been considerable discussion and some difference of opinion about the value of this test. Your committee has consistently adhered to the position that some sort of ductility should be shown at low temperature by asphalt for saturant and mopping. In this we are supported by various authorities on bitumen. We introduced it when the present specifications for membrane waterproofiing were adopted in 1934.

It has been said that the test is a little uncertain because asphalt is pretty sensitive at that low temperature. The committee, after consulting various authorities, decided that a rate of elongation of ¼ cm. per minute in the standard specimen required by the ASTM test, which is about 3 cm. long, would be a faster rate of elongation than would be encountered in actual service. Therefore, we thought it proper to reduce that rate so as to remove, or at least reduce, the possibility of premature rupture due to a mechanical jar or some cause other than lack of ductility. I move that we incorporate this change in the Manual.

(The motion was seconded.)

President Hastings: Is there any discussion?

Mr. Meyer Hirschthal (Delaware, Lackawanna & Western): I wrote to Mr. Lahmer on this subject, and I object to its inclusion at the present time, for two reasons: In the first place, it has been generally agreed between the various associations that the ASTM shall be the body to specify materials and tests, whereas we are the body to specify design, loadings and matters pertaining to railroads.

The second point to which I object is that this change is going to reduce the rate of ductility to one-fourth of the present rate, and still maintain four as the measure of that ductility. Therefore, this material is going to be one-fourth as ductile as the one we are specifying at the present time. This matter of testing for low temperature has been up for about twenty years. It is the same old story; the producers would like to see it out because it limits their ability to take the run of the refinery as waterproofing asphalt or pitch. Ever since 1920 I have made inquiries of independent laboratories, which aren't connected with producers, and they found they could make that ductility test at a low temperature, without any difficulty. However, it is true that most of the laboratories make use of a manually operated ductility machine, whereas the private laboratories have been equiped with an electrical device whereby they can control the speed specified, maintain the low temperature, and still keep the sample from fracturing, if it has the required ductility at low temperature. If the difficulty, as stated by Mr. Lahmer, is so general among the producers that they have refused to meet the specification unless some modification is made, I would suggest that this action be deferred for another year.

Chairman Lahmer: That statement was not made, Mr. Hirschthal.

The producers admit they can meet the test but that there is more or less uncertainty on account of the rapid rate of elongation. The test briquet has a length of 3 cm. between clips. The committee takes the view that the rate of elongation we propose (¼ cm. per minute) is very much faster than will be encountered in actual service. We are not prepared to say that 4 is the correct amount of ductility at that temperature, and the other authorities with which we are familiar, haven't said that. In fact, some of them said that they were not sure what is right. But we do want a ductility at a low temperature. Whether that is 3 or 3½ or 4 is a question. The committee believes that a ductility of 4 cm. at 40 deg. F. is an indication of the quality that is desired in waterproofing asphalt. We were unable to ascertain how the rate of 1 cm. per minute came to be selected.

Mr. Hirschthal: That rate was introduced in a specification prepared by a committee in which the producers at that time predominated.

Chairman Lahmer: We have gone about as far as we can in investigation and consultation with authorities. There are good authorities who contend we don't need a low temperature ductility test; that if an asphalt meets the requirements for softening point, penetration, and ductility at 77 deg. F. it will have a satisfactory ductility at 40. As I have already stated it is uncertain just what that low temperature ductility should be. The ASTM subcommittee which handles that subject had the method of making ductility at low temperature under consideration last year, and gave as the reason for not submitting a new method that they believed it would be necessary to devise a new machine for making the test, and that that would require funds which were not available. Therefore, it looks as if no help is coming from that source at present. We studied it the best we could, and this is the result.

Mr. Hirschthal: I sent you a series of tests showing ductility, penetration and all other qualities.

Chairman Lahmer: My recollection is that you sent me reports of tests of nine samples. Three complied with specifications for softening point, penetration, and ductility at 77 deg. F and these three showed substantial ductility at 40 deg. F. Five failed to meet requirements for ductility at 40 deg. F. and each of these five failed to meet one of the other requirements. The ninth was so far out of line that it seemed proper to disregard it or to call for a retest.

President Hastings: I think the convention has ample information before it from the debate which has so far taken place. However, I would like to ask whether Mr. Hirschthal wishes to offer an amendment. We have a motion to adopt. Mr. Hirschthal suggested that it be referred back to the committee for further study. There is no amendment to the motion.

Mr. Hirschthal: I prefer that the chairman himself withdraw the recommendation.

Chairman Lahmer: We feel we have gone about as far as we can, in the light of present information. We shall be glad to reopen the question at any time, when additional information is available.

President Hastings: Then it seems to the Chair that the thing we want to do is to vote on the question. Is there any further discussion of this? If not, are you ready for the question?

(Chairman Lahmer's motion was then put to a vote and carried.)

Chairman Lahmer: The next revision of the Manual is to change the first sentence of paragraph 7, Section 301 of the present specifications, which cover the application of membrane waterproofing. The Manual now says that coal tar pitch shall not be heated above 250 deg. F. and asphalt not above 350 deg. F. We propose to change that to read as follows:

> "Coal tar pitch shall not be heated above 250 deg. F., except that under unusual conditions, such as low temperature or long distance from kettle to point of application, it may be heated to a maximum of 325 deg. F., to facilitate mopping."

The other sentence will remain as it now reads: "Asphalt shall not be heated above a temperature of 350 deg. F."

In case there is a sudden change in the weather while a job of waterproofing is under way, especially in winter, resulting in a considerable drop in temperature, it might be advisable to heat the coal tar pitch sufficiently so that it would be workable after it reached the point of application, rather than to suspend work. As stated this is to be done only under unusual conditions. I recommend its adoption.

(The motion was seconded, put to a vote and carried.)

Chairman Lahmer: The next change has reference to Section 212 of the Manual, which covers plastic cement having an asphalt base. Requests have been made both by producers and by railroad users for a specification for plastic cement with a coal tar base. We consulted available specifications, including federal specifications. Rather than write an entirely and additional new specification for plastic cement having a coal tar base, we remodeled the present matter in the Manual as shown in Appendix A, so that it would cover both asphalt base and coal tar base, and so that the same tests would apply to each. In other words, we are putting coal tar plastic cement on a parity with the asphalt plastic cement.

I move that this be included in the Manual in place of the present Section 212.

(The motion was seconded.)

President Hastings: Is there any discussion?

Mr. Hirschthal: This Appendix A specifies the qualities of the asphalt but I fail to see any qualities for the coal tar pitch.

Chairman Lahmer: We didn't have any definite characteristics for the coal tar pitch available, and we were convinced that by specifying tests which would indicate what kind of service we want of this plastic cement, whether it be asphalt or coal tar, we would get the kind of material we want. We believe that will be sufficient.

Mr. Hirschthal: I am heartily in accord with putting a specification in a form where two competing materials will meet the exact physical requirements on the job, but it seems to me that if we waive the chemical or laboratory physical tests of one, we should waive them in the other; put them on a parity.

Chairman Lahmer: The committee is willing to accept that.

President Hastings: It is understood that this paragraph 2 of 212 will terminate with the word "blown", and the balance of that paragraph will be eliminated. Is that satisfactory?

Mr. Hirschthal: I would rather see that whole second paragraph out so it won't look as if we are specifying anything as to the laboratory test on asphalt or the method of production. We don't specify anything on coal tar pitch. Why not make the same provision for asphalt and simply leave the whole thing as a physical requirement?

Chairman Lahmer: The committee has very consistently adhered to the requirement for a good, straight steam-refined asphalt petroleum. We don't like to eliminate that. In a way, that is the key to the ductility at 40. We don't want a blown or oxidized product.

Mr. Hirschthal: Don't misunderstand me. I don't object to this at all. As a matter of fact, I insist on that in any specifications with which I am concerned, but simply from the point of view of a parallel specification for two competing materials, the method of treatment of the two materials in the same section of the specification should be identical.

President Hastings: Would it not be better, Mr. Hirschthal and Mr. Lahmer, because of the fact that there does seem to the Chair to be an inconsistency in putting in a specification a paragraph that calls special attention to one of the materials and not to the other, to eliminate the entire paragraph 2 for the present, and then next year endeavor to bring in a paragraph that would cover both the asphalt and the coal tar?

Mr. Hirschthal: Moreover, I would see where in one you can say "semi-solid asphalt formed from either a fluxed native or a straight steam-refined asphalt that has not been oxidized." Put your definition in (a).

Mr. G. E. Boyd (Railway Age): I think all of the material ahead of the word "blown" in the third line of Section 2 should be retained. There seems to be good reason why the remainder of that paragraph, including the two tabular lines, should not be eliminated. I think we do not want to leave the way open for anything other than a fluxed native asphalt which has not been oxidized or blown. The minute you leave the door open for materials of that kind you are quite likely to get a very brittle non-ductile material. I don't think we want to leave the way open for that to happen.

Vice-President Fanning (from the floor): I am rather in sympathy with the suggestion which Mr. Hirschthal made, to take the essential part of the second paragraph and insert it under (a). I don't know exactly what it should say but you might say "a fluxed native asphalt or a straight steam-refined asphaltic petroleum residual that has not been oxidized or blown." Put that up in (a).

Chairman Lahmer: You can take the first part of the paragraph down to and including the word "blown" and put it after (a) in paragraph one.

Mr. Fanning: That will be satisfactory.

President Hastings: Is that satisfactory, Mr. Hirschthal?

Mr. Hirschthal: Yes.

President Hastings: It is satisfactory to the committee. We will vote on the question as revised. Are you ready for the question?

(The motion was put to a vote and the paragraph as revised was adopted.)

Chairman Lahmer: The next revision is much the same, but with reference to protective cover. We have specifications for various protective covers to prevent damage to membrane waterproofing by ballast or something of that sort. The present specifications include asphalt mastic protective cover and it was suggested that we should provide for coal tar mastic protective cover in view of the fact that we permit use of coal tar as well as asphalt for saturant and mopping. So we have submitted the necessary revisions in the matter in the Manual. Those changes are found in Appendix B.

I move that they be substituted for the present matter in the Manual.

(The motion was seconded.)

President Hastings: Moved and seconded that the items on page 447, that is item 213. Asphalt Mastic, and 213½. Coal-Tar Pitch Mastic, also, that carries over to the paragraphs on page 448—

Chairman Lahmer: I failed to call attenion to a slight change on page 448. It says in new paragraph 6: "The asphalt, or asphalt and asphalt mastic cake, or coal-tar pitch shall be melted in the kettle, heating to 250 deg. F. for coal-tar pitch mastic and to 350 deg. F. for asphalt mastic." The coal tar pitch that is used in this mastic is harder than the coal tar pitch that is used for saturant and mopping. Inadvertently, we specified the same upper limit for heating (250 deg. F.) which is specified for coal tar pitch for saturant and mopping. The upper limit should be 300 deg. F. for coal tar for mastic, merely because the base coal tar has a higher softening point.

President Hastings: You revise the 250 in the second line of paragraph 6 to 300?

Chairman Lahmer: Yes.

Down toward the end of the paragraph it says: "The ingredients shall be well mixed with iron stirring rods." We want to change the word "the" to "these" so it will read "These ingredients shall be well mixed," etc. At the end of the paragraph we wish to add: "The mineral filler shall then be uniformly incorporated in the mixture." That simply means that the fine and coarse stone and the bitumen are to be mixed and heated in the kettle. Then, after they are well mixed, the mineral filler shall be incorporated. Specimens have been made in the laboratory according to these specifications and they appear to be a satisfactory product.

President Hastings: Just where in the paragraph are those words?

Chairman Lahmer: After the word "mixture" in the next to the last sentence, add "The mineral filler shall then be uniformly incorporated in the mixture."

At the end of the paragraph, after "400 deg. F." we wish to insert following the saving clause as a part of that paragraph: "and shall not be heated above 375 deg. F. for a longer period than 20 minutes."

With these changes, I move that the matter be included in the Manual.

President Hastings: We already had a motion, Mr. Lahmer, before we pointed out these corrections. The Chair will permit the corrections after the motion. You have heard the chairman explain the revisions of the printed text. Is there discussion?

(Chairman Lahmer's motion was then put to a vote and carried.)

Chairman Lahmer: That concludes the report, except that under Assignment 2 "Waterproofing and dampproofing of railway structures" we submit a statement for information, to the effect that we are opposed to lowering the requirements for bitumen in our membrane waterproofing specifications in order to meet the revised and lowered requirements of the American Society for Testing Materials, and that asphalt from Mexican crude which will fully comply with our specifications is again beginning to appear in our market.

That is the end of the report.

President Hastings: That completes this committee's report. This report has provoked some discussion, and the Chair wishes to say that he is glad that a number of reports this year did bring forth some discussion.

You need not feel worried, Mr. Hirschthal, that you had to bob up several times. Certainly the chairmen of these committees and your Board of Direction as well as the membership are delighted to know that we have members that carefully study these reports and come here prepared to discuss them, even though in the discussion they don't always gain the point that they have presented.

Mr. Lahmer, we thank you and your committee very much for the work they have done this year. They are excused with the thanks of the Association. (Applause)

Discussion on Iron and Steel Structures

(For Report, see pp. 407–444)

(President Hastings presiding.)

Chairman R. A. Van Ness (Atchison, Topeka & Santa Fe): The members of the committee were saddened in December to learn of the death of Philip George Lang, Jr., who had served on this committee for the past sixteen years.

The first subject of the report, Revision of Manual, will be given by Mr. Selby.

Mr. O. E. Selby (Cleveland, Cincinnati, Chicago & St. Louis): On page 408, the committee offers and recommends for adoption one definition which I will read as proposed, and this is a slight revision from the printed form.

> "Angle of Skew.—The angular deviation of one of two intersecting lines from a line at right angle to the other."

I move the acceptance of this definition for the glossary.

(The motion was seconded.)

Mr. Meyer Hirschthal (Delaware, Lackawanna & Western): I am repeating what I wrote. I think it would be much simpler to make the definition read: "Angle of skew is the complement of the angle formed by two intersecting lines."

President Hastings: The Chair rules that as this is a definition it is not subject to amendment or discussion. It either must be accepted, rejected or referred back to the committee.

(Mr. Selby's motion was then put to a vote and carried.)

Mr. Selby: Continuing on page 408, the following revisions of the Specifications for Steel Railway Bridges are recommended. These revisions do not in any case affect the substance or the intent of the specifications. They were written to clarify certain phrases which had been subject to the possibility of misunderstanding. I will read the titles and at the end move their adoption.

(Mr. Selby then read the paragraph headings beginning with 206 p. 15–6 down to and including 423 p. 15–15.)

Mr. Selby: The committee desires to withdraw the recommendation as to 504 p. 15–20.

(Mr. Selby then read the balance of the paragraph headings on page 409 and down to and including the second paragraph heading on page 410.)

Mr. Selby: The reference A7–36 should be changed to A7–39.

(Mr. Selby then read the paragraph headings beginning with Alloy Steels p. 15–45 and down to Appendix A. p. 15–48.1 on page 410.)

Mr. Selby: This is a rather extended substitution in the formulas for compression members, to take account of compression members in which the known eccentricity is eccentric in two planes.

Mr. Hirschthal: May I call attention to the fact that the square root signs should include the denominators as well as the numerators in these formulas. The square root of fp divided by E should include the E.

Mr. Selby: I think that is correct. That correction will be made. I call attention to an omission on page 411, following line 11 which reads "55,000 for nickel steel." There should be inserted a line reading: "f = factor of safety based on yield point" and the following three paragraphs should be indented to show that they are subordinate to that definition of factor of safety.

I move the adoption of these revisions of the Specifications for Steel Bridges.

(The motion was seconded, put to a vote and carried.)

Mr. Selby: Beginning at the middle of page 411, the following revisions of the Rules for Rating Existing Iron and Steel Bridges are recommended.

(Mr. Selby read the paragraph headings of the revisions of the Rules for Rating Existing Iron and Steel Bridges beginning at the middle of page 411.)

Mr. Selby: At the top of page 412, in the formula for "f" following the second equality sign, insert after the words "critical frequency" the words "of the span, vibrations per second" making this member of the equation read:

> "the second or higher critical frequency of the span, vibrations per second, resulting from locomotive spring action."

(Mr. Selby read the paragraph headings found beginning at the top of page 412.)

Mr. Selby: Under 115 p. 15–127, at the beginning of the paragraph to be substituted, insertion should be made of the words "Stresses in" so it will read "Stresses in plate girders, I-beams and other members subject to bending," and so forth.

Mr. President, I move the adoption of these revisions of the Rules for Rating Existing Iron and Steel Bridges.

(The motion was seconded, put to a vote and carried.)

Chairman Van Ness: Subject 2: Specifications for fusion welding and gas cutting for steel structures, collaborating with ASTM Committee A–1 on Steel, and the American Welding Society Conference Committee on Bridges. No report.

3. Non-ballast type of solid deck steel bridges. Progress in study—no report.

4. Design of expansion joints involving iron and steel structures. Progress in study—no report.

5. Design of connections in which rivets develop tension. Professor W. M. Wilson will present the report.

Professor W. M. Wilson (University of Illinois): As chairman of the subcommittee on this subject, the speaker presented a discussion which was offered for publication as a subcommittee report, but Committee 15 recommended it for publication as a monograph which was published in the Bulletin 412.* It is too long to be read, but I do want to present briefly the line of thought that has been developed.

The primary function of the connection angles of stringers of through bridges is to transmit the shear from the end of the stringer to the floor beam. Although this is the primary function of the connection, the deformation of other parts of the structure subjects the connection to stresses that are secondary to its primary function.

The elongation of the bottom chord of through bridges tends to increase the distance between adjacent floor beams and thereby subjects the outstanding legs of the connection angles to a bending moment and subjects the rivet in the outstanding leg to both tension and flexure.

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* Reprinted on page 889 of this volume.

Moreover, the deflection of the stringer subjects the connection to a moment which, as usually designed, it is not strong enough to resist, and this moment also produces stresses in the outstanding legs of the connection angles similar to those produced by the chord lengthening. In both instances, the stress is due to the relative motion between the adjacent members of the structure. It is what is known as a deformation stress as distinguished from a load stress. In designing for a load stress, we provide strength; in designing for a deformation stress we provide flexibility.

There is another unique characteristic of a deformation stress. When a deformation equals the elastic deformation corresponding to a yield-point stress, considerable further deformation causes no appreciable increase in the stress due to the yield-point characteristic of structural steel.

The stress in a connection is derived largely from a small group of wheels and, to a lesser degree, to the train as a whole. The cycles of stress may therefore occur many times during the life of a structure. Moreover the dead-load stress in a connection is almost zero, and the stress cycle is one in which the stress varies from practically zero to a maximum. The design of a connection is therefore a problem in fatigue.

With this background before us, I will now present an outline of the monograph. It is made up of the following parts:

1. Computations for a typical bridge, showing the magnitude of the deformation of the connections due to the design load, that is, the deformation that must be provided for.

2. Computations for a typical connection showing the deformation corresponding to a yield-point stress. This is the deformation that can be permitted without danger of failure.

3. An analysis of the fatigue tests of connection angles reported in the University of Illinois Engineering Experiment Station Bulletin 317.

4. Connection failures in service as reported by members of Committee 15.

These four studies resulted in the following paradox:

The deformation of the usual connection corresponding to a yield-point stress is much less than the computed deformation due to chord shortening and stringer deflection due to the design load. Although some connection failures occur, they are not really very frequent. These two statements appear contradictory, but the paradox is explained as follows:

Because of the yield-point characteristic of structural steel, the deformation can be several times greater than the elastic deformation at the yield point without producing a stress greater than the yield point.

The fatigue tests show that a connection angle can be subjected to a yield-point stress many thousands of times without failure.

After presenting the three studies, the analyses, the fatigue tests and the experience of the railroads, the monograph ends with a specification for design practice.

The monograph was published as such, after having been presented to Committee 15 as a report of the subcommittee, the reason given being that it was the work of one man and not of the subcommittee. Whether that reason is true or not, I will not hold the committee responsible for the statements that are made. However, I do wish to give credit for constructive criticism received from members of the committee.

To be specific, the recommended practice contained in the monograph was originated by Professor T. C. Shedd, a member of the subcommittee, and I am glad to make acknowledgment at this time.

The recommended practice is that the gage of the outstanding leg of the connection angle be made equal to $\sqrt{\frac{Lt}{8}}$ for the upper one-third of the connection angle. In other words, the gage should increase with the square root of the span and should increase with the square root of thickness.

The proposed design formula results in a somewhat more flexible connection than is used by most designers but not more flexible than is used by some designers of high standing. It does not result in a flimsy connection. It is an effort to design a connection so as to provide flexibility.

This is presented as information.

President Hastings: Professor Wilson, the Association is very much indebted to you for the splendid paper, to which I made reference in my annual address on Tuesday morning. It is a most valuable addition to the literature of this Association.

Chairman Van Ness: Subject 6: Review specifications for overhead highway bridges of the American Association of State Highway Officials in so far as they relate to steel construction, conferring with that association. No report.

7: Progress in design of steel bridge details. Mr. Leffler will present this report.

Mr. B. R. Leffler (New York Central): Appendix B begins on page 412, and presents a study of bridge details. It is divided into two parts. The first part is an exhibition of faulty details as experienced and observed by various railroad bridge engineers of the country. We might call this part, using a medical term, the "pathology" of bridge details. It is sort of a morbid subject, but we should not hesitate to study our faults and troubles. I made a synopsis of some of the leading features, but you can only get the full benefit of this report by studying it. It pertains, in particular, to those parts of railroad bridges having relatively small dead load, together with many applications of live load. This should be kept clearly in mind. We are studying the bad effects of fatigue in parts of a railroad bridge. I will refer to some of the principal sketches appearing in the report.

Fig. 1 is a typical design found in bascule bridges of a certain well-known type. Six bridge engineers reported failures of the type indicated in this sketch.

The bad effects of re-entrant cuts are illustrated in Fig. 3. It shows a floor-beam web which has a re-entrant cut, and the designer or fabricator, or both, attempted to guard against spreading cracks by boring a hole. You have heard the old story of the cracked window pane. A hole is bored at the end of the crack to prevent it from spreading. That didn't work in this floor beam.

The bad effects of varying pressure between a pin and a pin hole are well illustrated in Fig. 1, already referred to and in Fig. 13, and Fig. 30–B. Many illustrations of this interesting phenomenon and experience are found in existing structures.

Fig. 29 is an interesting one. There, we illustrate the effects of re-entrant cuts in a floor beam web, such cut being roughly gouged out in the fabrication. There is another feature that I want to call attention to, which I should have mentioned in the beginning: The failures shown are all in structures that have given service for many years. That emphasizes the fatigue nature of the failure.

This Fig. 29 shows one of the most remarkable cases of fatigue failure. I have forgotten the exact service life of this detail, but I should say about thirty years under very heavy traffic.

Fig. 28 shows how a connecting plate with a single pinhole may fail. The failure occurred after about thirty years of service.

In Fig. 17, we have an illustration of a failure of one of two things, which were not intended to work together. That often happens when the designer assumes that the one part will carry all of load, forgetting that the other is going to deform and carry load also.

In Fig. 16, the upper part is an example of a floor beam failure in the web. The cause was not foreseen at the time of designing. The discussion in the report tells you just what happened.

The second part of the report consists of a discussion of principles, beginning near the top of page 438. At the top of page 440, attention is directed to some of the results brought out in fatigue tests reported in Bulletin 302 of the University of Illinois. The table is an interesting one. The average unit stress at failure for 2,000,000 repetitions of stress is 21,200 lb. I am referring to the bar five inches wide, with an unfilled hole in the middle. Similar tests on bars without a hole gave an average unit stress at failure of 30,300 lb. per sq. in. The first figure given, 21,200 lb., is the average unit stress on the section through the hole. Of course, there being no hole in the second bar, the average unit stress is for the whole section of bar. There is a drop in the stress from 30,300 lb. to 21,200 lb.

Beginning at the top of page 442, the committee has made some rather startling statements and I will give them to you in a more startling manner. We do not know how to design a simple tension member with a hole in it. This is one of the problems of Committee 15. You could write a volume on that. Contrary to current engineering belief, it is practically impossible to design a tension member with positive assurance that the maximum unit stress will be less than the yield point.

Some one may say that in a modern, new bridge, we don't have these troublesome details. I am not so sure about that. At any rate, the subject is a live one with respect to old bridges, and there are still many in use. The report states that this subject of rating bridges requires a more careful study. I think I have said before this Association several times that it requires far greater skill and better judgment and greater experience to rate an old bridge than to design and build a new one. Referring in particular to the floor system, it is not safe to assume that, because a bridge has carried a certain loading successfully for many years, it will do so in the future.

Now, we engineers want to think of that carefully because we are, in our daily work, closely associated with the Operating department, and if there is one fallacy that confounds an operating superintendent, it is the doctrine that, because a certain loading has been carried by a bridge for years, it must be safe. This report is a complete refutation of that statement. Under certain conditions a crack may develop at any time.

Mr. Chairman, that concludes my presentation of Appendix B.

Professor Wilson: I feel that the engineering profession could profit more by its mistakes than it has in the past. Our railroads constitute a field laboratory but we have not always even collected, let alone evaluated, the data that have become available from actual structures under actual operating conditions. The profession is indeed indebted to Mr. Leffler for having collected data relative to the failure of bridge details and for giving his explanation of their occurrence. We need more work of the same kind.

Mr. Leffler attributes most of the failures which he has reported to fatigue. In this he is probably correct. The idea that fatigue of structural members and connections is of importance in structural design is comparatively new. Recent tests in Europe and in the United States indicated that structural plates of a riveted joint when subjected to a stress that varies from zero to a tension of 26,000 lb. per sq. in. may fail at 2,000,000 cycles, and that it will fail at approximately the same number of repetitions of a cycle in which the stress varies from 20,000 lb. per sq. in. tension to an equal compression. Moreover, these statements are true whether the plate is of carbon steel with a static strength of 63,000 lb. per sq. in., a silicon steel with a static strength of

80,000 lb. per sq. in., or a nickel steel with a static strength of 99,000 lb. per sq. in.* These statements apply to riveted joints fabricated by modern methods and which have plates without re-entrant cuts. Plates with re-entrant cuts may have a fatigue strength as low as one-third or one-half of the above values. This being true I fully agree with Mr. Leffler that the failures of details that he has reported are probably due to fatigue. I agree with him further that the problem of faulty details is a serious one and that details and main members that are subjected to a large number of reversals or repetitions of stress should be carefully designed so as to avoid stress raisers.

Our difficulty is to recognize that there are certain types of members and details that may fail in fatigue, and provide for their proper design without unnecessarily increasing the size of other members not subject to danger of fatigue failure.

When we stop to consider the action of a bridge we realize that there are very few members subjected to a reversal of stress. Furthermore, for most bridges, the members subjected to a reversal of stress receive relatively few cycles during the life of the structure. Moreover, the engineer designs for the combination of circumstances that produces the maximum possible stress. The probability of those circumstances all occurring at the same instant is very remote, so the maximum stress in most cycles is very much less than the maximum possible stress used in the design, and repetitions of a low stress contribute little if any to fatigue failure.

I am not making these statements to belittle the possibility of fatigue failure but rather to prevent undue alarm. Tests show that the bridge engineer must consider fatigue, particularly with alloy steels. It is for this reason that Committee 15 is studying and will continue to study fatigue. It is for this reason that Committee 15, by action approved by this convention only a few minutes ago, has stipulated that, until more information is available, the same unit stress will be used for alloy as for carbon steel in designing bridge floors. Otherwise, the possibility of a fatigue failure has not caused any great change in our design procedure except that it has made us realize the necessity for more complete knowledge relative to the fatigue strength of structural members.

Mr. Leffler: I won't tell too many family secrets, but when Professor Wilson brought out this study in Bulletin 302 I was very skeptical about it, and suggested to Committee 15 that we had better study the subject from a practical standpoint by actual examination of details. Appendix B is the result of that study. I still don't believe that the stress at the edge of a hole is three times the average, although I believe that it is much greater than the average; but whether it is three times or not has been much disputed by good mathematicians, for instance, Professor George Swain.

I wish to direct attention to a correction in the report. Assignment No. 7 in the foreword on page 407 should read: "Progress in design of steel bridge details (Appendix B). Progress report." The last paragraph at the bottom of Page 444 should read: "This report is presented as information." It is desired that engineers submit to Committee 15 further details with discussion and remedies, so that the study may be continued.

Mr. J. F. Leonard (Pennsylvania): I would like to ask Mr. Leffler or Professor Wilson, if as the result of their studies of fatigue values, they could enlighten the designer as to the propriety of using bent plates as a substitute for angles?

Professor Wilson: I have no information regarding bent plates.

Mr. Leffler: I have made considerable use of bent plates for the purpose of obtaining the flexibility which was brought out in Professor Wilson's monograph. With a bent plate, you obtain a wide outstanding leg. By making the plate thin enough, you get the desired flexibility.

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* University of Illinois Engineering Experiment Station Bulletin 302, Table 40, page 103.

Mr. Leonard: I would like to ask also whether the committee has given consideration to the use of cold-driven rivets and to the flame cleaning of structural steel.

Chairman Van Ness: On the question of gas cleaning of steel, the committee has never considered that as a committee subject or even discussed it to any extent. As to the subject of cold driven rivets, the committee has often discussed this subject. We haven't gone into it as a committee subject because it involves a patented device.

President Hastings: It might be well, Mr. Chairman, for the committee to consider those items in its deliberations, looking to some recommendation to the Committee on Outline of Work, if it was thought wise to pursue those subjects.

Chairman Van Ness: That is your thought on gas cleaning, particularly, Mr. Leonard?

Mr. Leonard: It is on both subjects. In the case of cold driven rivets, while, in a sense, I believe certain patented processes are involved, the subject doesn't necessarily involve them. Since they are used, I believe, in a number of cases, it seems to me that we are not keeping ourselves fully informed in not giving them consideration. Perhaps some kind of a specification, might be considered.

In the case of the flame cleaning, it is my personal opinion that, in view of the practice which has developed within the last several years among many of the outstanding consulting bridge engineers of the country, it is only a questions of time when that will be almost universal.

Chairman Van Ness: The committee will be glad to consider the gas cleaning of steel during the next year. In regard to cold driven rivets, there is some question about the economy as compared to hot rivets, but the committee will be glad to go into that again this year, and it may see its way clear to make a recommendation to the Outline of Work committee.

This completes the report of this committee.

Presiden Hastings: Committee 15 is anoher one of those fine committees of the Association that always brings in a very splendid report. You need not be afraid for a moment that I am going to discuss the report. I never discuss questions with doctors. Instead of that we are going to thank the committee very much indeed for the splendid work it has done for the Association.

Discussion on Wood Bridges and Trestles

(For Report, see pp. 323–350)

(President Hastings presiding.)

Chairman H. M. Church (Chesapeake & Ohio): The committee desires to report progress in study on the following subjects: 1. Revision of Manual; 3. Overhead wood or combination wood and metal highway bridges; 4. Specifications for design of wood bridges and trestles, and 5. Bearing power of wood piles; 7. Design of timber structures; 8. Review specifications for overhead highway bridges of the American Association of State Highway Officials in so far as they relate to wood construction, etc. and 9. Fireproofing wood bridges and trestles, including placing of fire stops.

With respect to subject 2: Simplification of grading rules and classification of timber for railway uses, collaborating with other organizations interested, the committee is not in a position at this time to present information on progress in the review of the material now in the Manual. This is being handled by the Bureau of Standards and Central Committee on Lumber Standards. We have, however, included a report under this heading, and in the absence of Mr. Newlin, Mr. Austill will offer a few remarks pertaining to the matter submitted in Appendix A.

Mr. H. Austill (Mobile & Ohio): This material is particularly informative and is presented to elaborate upon material which is now in the Manual, but is not offered for adoption.

President Hastings: It will be received as information.

Chairman Church: Subject 6 has reference to recommended relationships between the energy of hammer and the weight or mass of pile for proper pile driving. Collaboration with Committee 8–Masonry, has resulted in the preparation of Specifications for Driving Wood Piles. As Mr. Heinlen, chairman of the subcommittee, is not present, I will briefly state that this material was presented last year, practically as shown here, as information. Since we are offering this for inclusion in the Manual, and as there have been very few changes, I will just point out the minor corrections that we desire to offer.

(Chairman Church read the paragraph headings under Appendix B, beginning with page 326 and down to "(k) Replacing" on page 329.)

Chairman Church: There is a change here, in that the former heading, (k) Splicing, and the accompanying paragraph have been deleted. Under 8. Framing, the committee desires to change the second sentence, eliminating the words "and asphaltum or" and substituting the words "coal tar" in place of "roofing pitch." The sentence will read: "The sealing compound shall be a mixture of creosote coal tar pitch, mixed to about the consistency of vaseline and brushed thoroughly into the wood." Under (c) Pile Covering, it is desired to eliminate the word "galvanized" so that various types of metals may be applicable for this purpose.

(Chairman Church read the balance of the paragraph headings.)

Chairman Church: It is the recommendation of the committee that these Specifications for Wood Piles be included in the Manual to supersede the matter on pages 7–51 and 7–52. I so move.

(The motion was seconded, put to a vote and carried.)

Chairman Church: The additional report of this subcommittee, Recommended Relationships Between the Energy of Hammer and Weight or Mass of Pile for Proper Driving, is submitted as information and, except for corrections, is a reprint of the information published last year. This is offered as information.

President Hastings: It will be so received.

Chairman Church: Subject 10, Specifications and Design of Fastenings for Timber Structures, Including Metal Joint Connectors. In the absence of Mr. Cornell, who made some previous reports, I am asking Mr. Smith to present this information.

(Mr. L. W. Smith, National Lumber Manufacturers' Association, read the first paragraph under Appendix C on page 331.)

Mr. Smith: This report is submitted as information.

President Hastings: Is there any discussion on this part of the report? It is offered as information and will be so received.

Chairman Church: Appendix D is on page 335. In view of the absence of the chairman of the subcommittee, Mr. Crites, I will present the subject. This information was included in last year's report, and it was the expectation of the committee that it would be recommended for inclusion in the Manual.

We have received some very constructive information and comments from Mr. Hirschthal, which have convinced the committee that this matter can be greatly simplified, and it is the hope of the committee that the subject will be continued. The committee therefore, wishes to present this report as information, and withdraw the recommendation that it be adopted for printing in the Manual.

President Hastings: Do you wish to call attention to anything particular that might be of interest to the Association in the matter?

Chairman Church: It appears that detailed specifications for the four bituminous compositions are not necessary as state highway specifications and methods of construction are satisfactory.

President Hastings: It is understood, then, Mr. Church that it is not the desire of the committee that your recommendation as printed in the Bulletin, namely, that this be presented as Manual material at this time, be carried out, but it is your desire that it be received at this time only as information and the subject continued.

Chairman Church: Yes.

President Hastings: Is there any discussion? If not, it will be so received, with the hope that you can bring in simplified specifications next year.

Chairman Church: That ends the report of the committee.

President Hastings: This committee has brought in a fine report this year. One specification has been adopted. I want to compliment the committee particularly on the fact that it is willing to withhold the second specification because attention has been directed to the possibility of having it simplified. We want to be sure that our material is a finished product before it goes into the Manual. It is much better to hold it before the Association for another year than to adopt it and then have to make extensive changes the following year. Those changes are expensive and the information is always just as available for study in the bulletins and Proceedings as in the Manual. The committee is excused with the thanks of the Association. Applause)

Discussion on Impact

(For Report, see page 476)

(President Hastings presiding.)

Chairman J. B. Hunley (Cleveland, Cincinnati, Chicago & St. Louis): For the last two or three years, the report of this committee has been practically "standing in type." In fact, it was so embarrassing last year that we didn't even appear on the platform, but since then we have been authorized to spend $4,000 in making investigations during the present year. I am rather ashamed to tell you that for that $4,000 we have obtained the services of three men, all of whom are very good. It will be impossible to make any elaborate tests until additional equipment is obtained, but we expect to make some oscillator tests and hope to obtain some additional information as to damping and also to analyze some of the tests that were made several years ago by the Pennsylvania Railroad at Chester and possibly those made at Elkton. Those tests are very valuable, and the Pennsylvania has kindly allowed us to use the data.

I am hoping before this year is over, that we will be able to report something that will not only be of interest but which will also justify a request for at least a similar amount of money, and prefereably more, for next year. That completes the report of this committee.

President Hastings: It is very gratifying that we were able to secure this year, as I mentioned in the annual address on Tuesday, $4,000 from the Association of American Railroads through the Research Committee of the Engineering Division, in order that Mr. Hunley and his committee, along with the Research Engineer of the Association of American Railroads, could carrly on this very important work. I feel very sure that the work thus started will be continued. The committee is excused with the thanks of the Association. (Applause)

Discussion on Track

(For Report, see pp. 553–607)

(Vice-President Fanning presiding)

Chairman W. G. Arn (Illinois Central): The first subject assigned is the revision of the Manual. The revisions are quite extensive, and many of them pertain directly to the work of the various subcommittees. Such changes will be presented by these subcommittee chairmen in connection with their reports.

General revisions of the Manual, which do not pertain particularly to these other subcommittees, will be presented later by Mr. Zeeman, chairman of the subcommittee on revisions.

The next assignment is revision of Manual in so far as it pertains to string lining of curves. This report will be presented by Mr. Strattman.

Mr. C. R. Strattman (Michigan Central): This report is found in Appendix B, pages 557–559. It is just a revision of what is now in the Manual, to clarify and make it more easily understood. I don't think it is necessary to read this report as it is clear. I move that it be adopted and printed in the Manual.

(The motion was seconded, put to a vote and carried.)

Chairman Arn: The second assignment is Fastenings for continuous welding of rail. The committee merely reports progress on this, and is continuing the observation of installations already made. No new installations have come to the attention of the committee.

The third assignment, Plans and specifications for track tools, will be presented by Mr. Roller, chairman of the subcommittee.

Mr. W. L. Roller (Chesapeake & Ohio): As the report of Subcommittee 3, Plans and Specifications for Track Tools is brief, I will read it.

(Mr. Roller read the report found under Appendix D on pages 560–564, down to the conclusions, and indicated that "Railway and Ballast" in the first line of the report should be changed to "'Roadway and Ballast")

Mr. Roller: The conclusions of the committee are as follows:

It is recommended that, due to certain corrections, criticisms and revisions that have been offered to Plan 20A–Wood Center Track Gage, this plan be held as information for another year.

We are offering for adoption Plan 27 shown on page 561. This is a new design of track level with elevation gage. We feel that it incorporates some very advanced features in the way of a ground vial for the bubble and a more sensitive level bubble. We offer this for adoption, and I so move.

(The motion was seconded, put to a vote and carried.)

Mr. Roller: We are also offering Plan 28–40, which you will find on page 563. This is for a 26-in. scythe. I move its adoption.

(The motion was seconded, put to a vote and carried.)

Mr. Roller: We are also offering for adoption Plan 29–40 found at the bottom of page 562. I so move.

(The motion was seconded, put to a vote and carried.)

Mr. Roller: Plan 30–40 at the bottom of page 563 we wish to offer for adoption, with a slight revision to include as material for the beam of the spot board, sugar pine as well as white pine. I move its adoption with this revision.

(The motion was seconded, put to a vote and carried.)

Mr. Roller: You will find on page 564 a design of timber tongs which presents some advanced features in the way of safety in handling, over the plan now in the Manual. We are offering this plan for adoption, and for withdrawal of the old plan.

(The motion was seconded, put to a vote and carried.)

Mr. Roller: Also offered for adoption is the physical test for timber tongs found at the bottom of page 560 and the middle of page 564. This test has been offered as information for two years. I now move its adoption and incorporation in the specifications.

(The motion was seconded, put to a vote and carried.)·

Mr. Roller: That concludes our report. It is recommended that the subject be continued.

Chairman Arn: The fourth assignment is a double assignment, plans for switches, frogs, crossings, spring and slip switches, and highways, on matters pertaining to track construction in paved streets. On the latter portion of the assignment, there is no report this year. Mr. Caruthers, the chairman of the subcommittee, will present the report on the first portion of the assignment.

Mr. E. W. Caruthers (Pennsylvania): The subcommittee has been engaged during the past year in a complete review of all of the trackwork plans. It has been some time since such a review has been made, and a number of the plans have become more or less obsolete through a number of inconsistencies.

The committee has endeavored to give thorough consideration to all of the plans. It was not possible during this past year to reissue or ask for recommendations on all of the plans, and an effort has been made to consider the plans that might be regarded as key plans. If they are accepted by the Association, the committee will then continue the work, and we hope to be ready at the next convention to present the balance of the plans, thus giving a complete series of revised plans.

Vice-President Fanning: There are 32 plans to be considered here and to be voted on. To save the time of the convention and to save my voice in putting 32 motions, I am going to ask Mr. Caruthers simply to read the number of each plan and to pause a moment. If there is any discussion on any plan, let us have it at that time, and then we will vote on all 32 at once.

(Mr. Caruthers then read the following plan numbers:

111–40
112–40
221–40
222–40
223–40
224–40
502–40
503–40
504–40
505–40
510–40
590–40
701–40
751–40
771–40
772–40
773–40
776–40
777–40
780–40
781–40
1005–40

He then moved the adoption of these plans as recommended practice and his motion was seconded, put to a vote and carried.)

Mr. Caruthers: Since releasing the plans for printing, the committee has found it advisable to withhold the following plans for further study:

Plan No.
241–40
401–40
405–40

Plan No.
640–40
670–40

The committee also presents as information:

Plan No.
793–40
1001–40
1002–40

Plan No.
1003–40
1004–40

Vice-President Fanning: They will be so received.

Mr. Caruthers: In view of the acceptance of the plans just acted upon, the committee further recommends the withdrawal of the following plans:

Plan No.
101
102
263
264
265
266
267
268
269
271
272
273
274
275
276

Plan No.
277
301–3
304–6
309
325
326
341–2
343–4
345
346
502
503
504
505
510

Plan No.
590
643
651–3
654–5
656
701
751
752
762
763
764
765
766
771
771–B

Plan No.
772
773
776
777
778
780
781
793
1001
1002
1003
1004
Appendix "D"

I move to withdraw those plans.

(The motion was seconded, put to a vote and carried.)

Mr. Caruthers: As the committee found it necessary to withdraw the five plans previously mentioned, the report has been changed to the extent that the following plans will remain in the book and not be withdrawn as recommended in the report. They are:

Plan No.
401
404
405

Plan No.
640
670

Vice-President Fanning: That is information.

Mr. Caruthers: That concludes the report of the subcommittee.

Vice-President Fanning: This is the beginning of a complete revision of the portfolio of trackwork plans, which it is contemplated will be reissued as Vol. 2 of the Manual.

Chairman Arn: The fifth assignment is: Corrosion of rails and fastenings in tunnels. The chairman of this subcommittee is Mr. A. E. Perlman, who will present the report.

(Mr. A. E. Perlman, Denver & Rio Grande Western, read the report appearing under Appendix F on page 570, with the following interpolation at the completion of paragraph d. Metal spray on sides of head of rail: "We found in the last few days that that is holding up very well.")

Vice-President Fanning: This will be received as information.

(President Hastings resumed the chair.)

Chairman Arn: Assignment 6 is: Design of Tie Plates for RE Rail Sections as Developed. Mr. J. de N. Macomb, chairman of the subcommittee, will present the report.

Mr. J. de N. Macomb (Inland Steel): The specification for hot-worked, high-carbon steel tie plates is found in Appendix G on page 571. Since the Bulletin was printed, the committee has decided to make two changes in the specification as it is offered.

The first is in Section 201 under "Chemical Properties and Tests" to strike out the reference to copper; that is the third line.

The other change is on page 572 under Section 401, paragraph (c). The variation of 1/64 in. in flatness of rail seat is changed to 0.025 in.

With those two changes, the committee offers the Specifications for Hot-Worked, High-Carbon Steel Tie Plates as shown on pages 571 and 572 for approval and publication in the Manual, and I so move.

(The motion was seconded, put to a vote and carried.)

Chairman Arn: The seventh assignment is Practicability of using reflex units for switch lamps and targets. The study and investigation of this has continued. There is no report to submit to this convention.

Assignment 8: Welding of manganese castings in special trackwork. Mr. Bishop, the chairman of this subcommittee, will submit the report.

Mr. F. J. Bishop (Toledo Terminal): The subcommittee's report is contained on pages 573 and 574. A report on the subject was presented to the Association in 1938. After a study of all of the available data on the welding of manganese castings in special trackwork, the committee decided that research work was necessary in order to improve the technique of manganese welding, and to determine the relative merits of coated electrodes and the advantage or disadvantage of nickel-manganese and other alloy-manganese base metal for castings. Accordingly, a program of research was prepared, the scope of which is indicated on page 573 by 13 different topics. These topics, as we go along with the work, may be revised, depending on our findings.

This program is designed to determine the most economical and effective welding technique and will result in definite savings to the railway industry by the elimination of unnecessary operations in welding, and longer service life of welds.

In order to obtain reliable information, the research plan proposes the establishment of a proving ground where the different welding techniques and recommended materials will be compared under actual, equal, and identical traffic conditions, the welding tests to be supplemented by such laboratory work as may be found necessary.

Through the assistance of the frog and switch manufacturers, your committee has obtained 24 special manganese test castings. These castings have been assembled in three units and have been installed by the Chicago, Milwaukee, St. Paul & Pacific Railroad in one of its heavy traffic freight tracks near Mannheim, Ill. A photograph of the castings as assembled is shown on page 574.

Your committee is indebted to the Milwaukee for the installation of the test castings as well as for furnishing the necessary rail for the casting assemblies and complete guard rail assemblies. The welding department on the Milwaukee will make all of the test welds required. We are likewise indebted to the frog and switch manufacturers as listed on page 574, for their very able assistance in furnishing the necessary materials. The frogs have not yet been welded as they have not worn sufficiently. We expect, however, in the course of the next few months to start the test welds.

The report is offered as information.

President Hastings: It will be so received. Is there any discussion of this portion of the report?

Chairman Arn: The next assignment is Bolt tension necessary for proper supporting of joints. Mr. Breed, the chairman of this subcommittee, will submit the report.

Mr. C. W. Breed: (Chicago, Burlington & Quincy): This report appears on page 574. The committee's progress report this year contains additional data on bolt tension from several test sections. One outcome of the test is the evidence of fairly uniform loss of bolt tension over a period of time.

The loss of tension over a ten months' period in the Burlington test, page 575, varies from 600 lb. to 1,530 lb. per month and is, in general, about 1,200 lb. per month.

On the Milwaukee, page 579, with no spring washers on bolts, the average monthly loss of tension is 850 lb. in the seven months' period. The Rio Grande & Western test, page 585, with comparatively high initial tension on the bolts shows a month's loss of 1,500 lb. over a 14 months' period.

In the Pennsylvania test, after 1½ months, there was a monthly loss of tension of 900 lb. The later tests should indicate more certainly what monthly or yearly loss of tension may be expected from bolts having certain kinds of thread fit and equipped with various spring washers. The efforts of the manufacturers of power wrenches to improve the automatic tension release have not been entirely satisfactory, as shown by a tabulation which indicates the wide range of bolt tensions. This lack of bolt tension is partially due to variation in torque delivered by the machine at time of kickoff, and possibly due, to a greater extent, to variation in screw thread fit of track bolt.

The increasing use of bolts and nuts having standard screw threads, applied by a force of not more than 25 lb. at the end of a 24-in. wrench should increase the uniformity of bolt tension. The subcommittee wishes to take this opportunity to thank Mr. G. M. Magee for his valuable services in carrying on the bulk of the work of the test.

This progress report is offered as information, and it is recommended that the subject be continued.

President Hastings: Gentlemen, this is a very interesting report on a very live subject. The research engineer of the Association of American Railroads, Engineering Division, is actively working with the committee in this matter, and the results that are being found are going to be tremendously helpful. We want to say right here that we appreciate the fine work that you are doing on this subject. Is there any discussion of this matter? If not, the report is received as information, with thanks.

Chairman Arn: The tenth assignment is: Lubrication of rail on curves. The study and investigation has continued, but there is no formal report for this convention.

Assignment 11 is Prevention of damage due to brine drippings on track structures. Mr. Magee, the chairman of this subcommittee, will submit the report.

Mr. G. M. Magee (Association of American Railroads): The subcommittee's report of this past year's work begins on page 590. It includes a description of test methods decided upon early last year, to study within the laboratory the possible benefits of various chemicals in inhibiting the corrosion of track and bridge structures by brine drippings from refrigerators. It is proposed, if a satisfactory inhibitor can be found, to add this inhibitor with the salt when the refrigerator car is iced.

The subcommittee is pleased to report that very encouraging results have been obtained with certain of the inhibitors included in the test this past year. The complete results of the test are included in the published report. Before definite recommendations are made for the actual use of the inhibitor, it is thought necessary to make tests first with the inhibitor used under actual track conditions. It is planned in the coming year to make trial runs with refrigerator cars containing inhibited salt. Brine drippings will be collected at intervals throughout the runs and analyzed for inhibitor content. This is for the purpose of determining whether the inhibitor will stay in satisfactory solution and diffusion throughout the test run.

It is also proposed to make some comparative tests in track by spraying salt solution daily on a section of track, and on another section of track to spray daily salt solution containing the inhibitor. The corrosion rate will be compared by weight loss.

This work has been carried out by a joint committee consisting of the Track subcommittee and representatives of the Mechanical Division. This joint committee is exerting every effort to arrive at a solution to this corrosion problem with which we have been so long confronted. The report is submitted as information.

President Hastings: You have heard the statement of Research Engineer Magee in this matter. A good many years ago, I recall very distinctly, our good friend, the late Mr. W. H. Courtenay, who was for years chief engineer of the Louisville & Nashville Railroad, made a significant statement when this subject of corrosion from brine drippings was before the convention. He said that we had been talking about it ever since he had been in the Association but it didn't seem that anything was being done effectively. We still have that problem with us, but it appears that we are now pursuing the subject in a very scientific way and that we are on the road towards success. We thank the committee for the fine work it is doing.

Mr. W. A. Radspinner (Chesapeake & Ohio): The fire protection fraternity has been accused of causing corrosion on bridge structures due to the fact that calcium chloride solution in fire barrels slops over on the bridges. I wonder if this committee intends to include that chemical in its investigation.

Mr. Magee: I am not familiar with what particular use or difficulty you had in mind. You say calcium chloride for what?

Mr. Radspinner: In the protection of fire barrels from freezing.

Mr. Magee: That is a good suggestion. The inhibitor will be equally effective with calcium chloride or sodium chloride. There is certainly no reason why it couldn't be used that way. It isn't at all expensive. One other use that has come up for it during the year, which we did not anticipate, was adding it with salt used around switches and metal platforms, particularly on cars. The inhibitor is effective in preventing corrosion of the plates by the salt and permits the ice to be kept from these platforms by this simple means.

Chairman Arn: The twelfth assignment is: Specifications for laying rails designed to set up the requirements for good workmanship. Mr. Schram, the chairman of this subcommittee will submit the report.

Mr. I. H. Schram (Erie): The report of Subcommittee 12 is found in Appendix K, page 599. The committee carried on extensive correspondence with most of the railroads of the country and obtained their specifications. After studying them, the report that is presented here was decided upon. The committee endeavored to take the most modern and the best practice from all the railroads. So, as a result, the specification as drawn does not comply with the requirements of any one railroad. However, the information is as general as we could make it. It is divided into several sub-topics: first, the location; second, the unloading; third, the preliminary preparation of the track; then the actual laying, and the final sub-topic, the completion of the work. This report is submitted as information.

The committee would very much like to have criticisms in writing from anyone who has any comments to make. We would like to have those so we can study the topic and, if necessary, revise the specification in the next year.

President Hastings: The subject is before you. This specification is submitted as information. The committee desires to have discussion of it either here on the floor or in writing, its plan being, as I understand it, to present to the convention next year a specification for inclusion in the Manual.

Is there any discussion of this specification for laying rail. If not, it will be received as information.

Chairman Arn: Assignment 13 is Methods of shimming track. There is no formal report but progress has been made on the study.

The fourteenth assignment is Spirals for high speed operation. Mr. Baldridge, the chairman of this subcommittee, will submit the report.

Mr. C. W. Baldridge (Atchison, Topeka & Santa Fe): The subject of spirals for curves has been before the Association since its beginning. On page 146 of Vol. 1 of the Proceedings is a report by the Track committee on the subject "Maintenance of Line" that includes a discussion of spirals for curves.

Again, in Vol. 2, beginning on page 255, is a seven-page report on spiral curves. More or less throughout the existence of this Association, the subject of spirals for curves has been reported upon by the Track committee, the most complete and well studied reports appearing in Vols. 7 and 12. The matter which is now in the Manual of the Association is largely that presented to the Association as reported in Vol. 12, except for a few minor changes made since that time.

The report which we are submitting at this time makes no changes in the principles involved. The subject assigned to the committee this year includes a report made by Committee 16 on this same subject last year. I do not know what brought the change about, but after last year's committee report was submitted as information, the subject was assigned to the Track committee for further consideration and further work, collaborating with Committee 16.

The subcommittee this year has held two meetings in collaboration with a subcommittee of Committee 16. It may be of interest to all concerned that there happened to be in those meetings exactly the same number of representatives from each committee.

We prepared a report in which a revision of the matter at present in the Manual was attempted, and also made plans whereby the work done by Committee 16 last year was to be included in place of the matter now in the Manual under the heading "Calculation and Staking of Curves by Offsets."

At the final meeting of the Track committee, to prepare the reports for publication, the work of Subcommittee 14 with the assistance of members of Committee 16 was presented. The text relating to revisions of what is now in the Manual, embraces a number of changes to which I wish to call attention.

> "The figure in the Manual to which reference is made for explanation of the terms and formulas, is retained after making a slight revision for the purpose of eliminating conflicting meanings given to certain terms as follows:
> "Capital letter *V* which is now defined as the distance on the tangent through *S.C.* from point *S.C.* to its intersection with the primary tangent through *T.S.*, which distance is the shorter spiral tangent, is changed to *Q* to avoid conflicting with *V* used to indicate velocity."

This change is made in order to accommodate the work of Committee 16 which, in the report last year, used *V* as train velocity in feet per minute, I believe.

> "Small letter *v* is also changed to small *q* for a like reason and for consistency.
>
> "Pages 5–23—Changes in definitions or letters representing various notations are as follows:
>
> "1. After *D* in the list of notations insert $E =$ Elevation of the outer rail on curves."
>
> "2. Following *I* insert small *i* and define $i =$ the initial deflection angle, which is the deflection for spiral chord No. 1.
>
> "3. Small *k*, change the definition to read $k =$ the amount of the central angle of the spiral subtended by the first chord thereof.
>
> "4. After *L* insert capital *N* and show $N =$ the length of spiral in chords between *T.S.* and *S.C.*"

This change is made because Committee 16 had used capital *S* as Speed of Trains in miles per hour or velocity of trains in miles per hour. Again, we would have the same symbol given with two definitions. Consequently, we substitute the *N* for *S*.

"5. Insert small *n* and show $n =$ length of spiral in chords from the *T.S.* to any given point on the spiral."

This is taking the place of the small *s*, for the same reason that the other changes were made.

"Page 5–24—

"6. Change definition of capital *S* to read $S =$ train speed in miles per hour.

"7. Change small *s* to read $s =$ train speed in feet per second."

Further changes in the present Manual are made or their position shifted as follows: "Calculation and Staking of Spirals." This is to be a subheading at the beginning of Notations and Symbols.

> "The notations and formulas herein apply to a ten-chord spiral based upon an increase in curvature proportional to the square of the lengths, measured in chords."

That information appears in the Manual at present but not in a conspicuous place.

> "Notations
>
> "(a) In designations for curve points, the first initial represents the alinement on the side toward station zero, the second that away from station zero."

The symbols remain the same on page 603 as they now appear in the Manual, down to the letter *E* which is a new insertion in this table. "$E =$ Elevation of the outer rail on curve." That, again, is used in the work of Committee 16. Lower down on the same page, small *i* is a new insertion. "$i =$ the initial deflection which is the deflection for chord No. 1."

The definition of *k* is changed to read "The central angle of the spiral subtended by the first chord thereof." After capital *L* insert capital $N =$ the length of the spiral in chords between the *T.S.* and *S.C.*", for the reason given before, that it conflicted with the work of Committee 16. Small $n =$ The length of the spiral in chords from the T.S. to any given point therein. Capital $S =$ Train speed in miles per hour. Small $s =$ Train speed in feet per second.

The figure given at the top of page 604 is much the same as one now in the Manual except we changed it from the right angle figure to one which would more clearly illustrate the ordinary curve, with a further change, namely, that the value *Q*, which is the shorter tangent of the spiral as it appears in this figure is the distance that was given as capital *V* in the previous figure.

Below the figure, small *q* is used to indicate the distance on the tangent, through any given point, from that point to the intersection with the tangent through *T.S.*, that taking the place of small *v*; capital *Q* also substituting for capital *V*, the distance on the tangent through the *S.C.* from the *S.C.* to the intersection with the tangent through the *T.S.*; the shorter spiral tangent.

The remainder of the symbols down to the heading near the bottom of page 604 remain the same. The heading "Known Quantities and Factors" is inserted as new matter, or at least different wording from what was in the Manual.

(Mr. Baldridge then read the paragraph headed "Known Quantities and Factors" on pages 604–605)

Mr. Baldridge: The only changes given in the formulas below are to substitute the new symbols for those that have been changed. At the bottom of page 605 is "Formulas for Field Use."

(Mr. Baldridge read the material under "Formulas for Field Use" at the bottom of page 605)

Mr. Baldridge: That is quoted from the present Manual. The matter on page 606 is quoted from the present Manual down to "Errors—Millionths of *L*." That small table is quoted from the Proceedings of this Association, Vol. 12, and was published at the time the matter now in the Manual was inserted. It is repeated here because it gives the degree of accuracy which applies to these formulas and will be of considerable value to the younger engineer who commences work in staking spirals.

In the Manual at present the next subheading is "Staking Spirals by Deflections." When this committee's report was submitted to the full Track committee, someone objected to the insertion of the work that we were taking from last year's report of Committee 16, because the determination of the superelevation of curves is based on a formula involving the use of a different value for gage of the track than that used in the formula now in the Manual.

By vote of the Track committee in that meeting, it was decided not to accept this material. It was then planned to adopt the remainder of Committee 16's work with four additional tables, but again the point was raised that the tables as prepared by Committee 16, with the formula for elevation which it had used, would not check with tables calculated by the formula for elevation which is now in the Manual.

It was therefore voted by the committee to withhold and refer back for further work the report of Committee 16. Instructions that have been issued off and on for the last two or three years are that the matter of reassignment is to be handled between the committee chairman and the Committee on Outline of Work.

Beginning below the table "Errors—Millionths of L" the work of revision of the Manual by this year's committee continues.

(Mr. Baldridge read the material under "Calculating the Curve" found on page 606)

President Hastings: I don't think it is necessary to read the language but call attention briefly to the principal points.

Mr. Baldridge: That is practically all. It is just an explanation of the calculation, deflection and staking of the curve.

On page 607 we have given instructions on how to apply the spiral to compound curves, and at the bottom of page 607 we give the recommendations.

(Mr. Baldridge read the recommendations found at the bottom of page 607)

Mr. Baldridge: The matter under "Staking Spirals by Offsets" is being left in place merely until we can finish our next year's work to revise the work or coordinate the work of Committee 16 and this committee to take its place.

I move that the recommendation be adopted.

(The motion was seconded.)

President Hastings: Moved and seconded that the recommendations be adopted. This constitutes a revision of the Manual and addition to material now in the Manual. Mr. Baldridge has made a complete and detailed analysis of this matter in his presentation. It is summed up in the three brief recommendations that you find at the bottom of page 607. Is there any discussion?

Mr. Geo. F. Hand (New York, New Haven & Hartford): I would like to ask Mr. Baldridge how his methods apply to the condition which we have encountered where we are in congested territory. Our tangents cannot be shifted; the central portion of the curves cannot be shifted materially. It seems to me that that feature is not covered here. We have to take other means of handling it. In other words, referring to the bottom of page 604, the report states that capital D is known or measurable. We find that capital D is not known or measurable because we have to adjust it to existing property or existing buildings. So, in spiraling the curve, we may have to change or adjust the central curve, and the calculation begins as a completely new one.

Mr. Baldridge: I do not know how you could apply your new curve without knowing what the curve is. That is measured. If you do not have any knowledge of what your present curve is, you must measure it in some manner to find out what kind of a curve you are going to put in. That is no different from new work, as I see it, you must know where to go.

Mr. Hand: I don't think you quite got the point, Mr. Baldridge, that we are in the position at times of not being able to shift the central curve materially or shift the tangents, and the calculation has to be a complete one right straight through, from tangent to tangent, without shifting the central curve materially. I am asking you if you feel that this report covers that condition.

Mr. Baldridge: As much as the previous matter in the Manual has covered it..

Mr. Hand: I am afraid that the previous matter didn't cover it completely.

Mr. Baldridge: I will say this much in that connection: We have endeavored to simplify the matter covering spirals, and the condition you describe is provided for by saying: "Where these rules cannot apply because curves are too close together" or because of other adverse conditions "the spiral must be adapted to the condition." I don't believe there is any use in trying to anticipate what those conditions are going to be in cases all over the country.

Mr. F. W. Droste (Chesapeake & Ohio): I would like to ask Mr. Baldridge, in connection with the changes of the letters in the spiral formula, if he has taken into consideration the letters used in spiral formulas as they exist in various textbooks.

A good many of the young men whom I have in charge at the present time are familiar with the present letters used in computing these spiral formulas.

These letters indicate certain fixed functions. For instance the letter *E* used in spiral formula represents the external distance, and letter *E* in the speed formula denotes elevation. The letter *I* has always denoted the angle between tangents. Should we not be consistent with the letters as set up in various textbooks when considering making revision of the Manual?

If one is using the spiral formula *E* will be the external distance. If using the speed formula *E* is the elevation. As the letters apply only to the formula that is being used, I really do not see the necessity for changing the letters in the Manual because they are in conflict with other formulas in the Manual.

Mr. Baldridge: The only change in the terms that we have made is to accommodate the letters that have been used by Committee 16, for instance, capital *S* for speed and the letter *V* for velocity, to give us something more firmly fixed for those meanings than anything else in here or any other textbook. In the use of *Q* in place of *V*, we took *Q* simply because it was not used anywhere else in here, and it was not likely to be used for any other purpose. I don't believe there are any other changes.

Mr. Droste: That may be very true. *E* is used for superelevation in these other textbooks. It is also used in spirals. I really don't see any necessity for changing the letters because the letters themselves apply to that particular equation.

Mr. Baldridge: It is necessary to change the letters if we are going to use the information given in this report and in the report of Committee 16, when we have it coordinated, because otherwise we would have the same symbol giving two meanings, or the same symbol would be given two meanings.

It was my judgment that we should use the more generally accepted definition for the letter *S* and for the letter *V* than to substitute something new for them. As far as whether or not the symbols used in our Manual agree with the textbooks, in the past this work has never done that any more than is indicated by what is now in the Manual.

Chairman Arn: In this connection, in view of the many symbols that have to be used by the AREA, the fact that we are a standardizing organization and hope to get these standards used, I don't think we should give too much consideration to what is in other publications.

As a matter of information, I might state in a canvass made of the Track committee—we didn't go outside for that—we found that, while a majority of the roads that answered the questionnaire did not use the AREA standard for spirals, the AREA standard was used more than any other spiral by the railroads represented on the committee, and a great many of the others, while they did not use the AREA spiral exactly as recommended, used it with slight modifications. I think, therefore, we are justified in having our own system of symbols.

Mr. Hand: Is it the intention of this committee or subcommittee to continue the study of spirals. If it is, I would like to suggest very strongly that it give consideration to the condition of which I spoke, that is location in areas so restricted that it is necessary to adjust both spiral and central curve to meet existing obstacles or property lines. I think there would be plenty of people interested in a method which would cover such a situation. I know there is quite a simple method which obviously cannot be discussed at this time.

President Hastings: I feel sure the subcommittee will continue its study and will take into consideration the things you bring forth, Mr. Hand.

(Mr. Baldridge's motion was then put to a vote and carried.)

Chairman Arn: That leaves only the revision of the Manual in general. Mr. Zeeman, the chairman of this subcommittee, will present his report.

Mr. M. J. Zeeman (Atchison, Topeka & Santa Fe): The recommendations for revision of the Manual are found on page 554. The first suggestion is to delete the reference to "Specifications for the laying of new track" which are now found on page 5–18, and refers by a note to the 1923 Proceedings, and insert the specifications as they are now shown in the 1929 Manual.

On the same page, 5–18, under the heading "Canting Rail" are two notes which are so self-evident that they are deemed out of date at the present time. It is recommended that this heading "Canting Rail" and the two notes be deleted. I move the changes of the Manual as outlined.

(The motion was seconded, put to a vote and carried.)

Mr. Zeeman: On page 5–33 is the subject "Maintenance of line." It is carried over for four paragraphs on page 5–34. The only thing that pertains to the line is one note on tangents which seems superfluous. It says the tangent should be adjusted between the summits, between curves, between a curve and a summit, and that the track centers should be set by the transit. The remainder of the text shown on this page and part of the next deals strictly with spirals. Since the subject of spirals has just been voted upon, it is recommended that all of that data on spirals, including the paragraph on tangents, be deleted from the Manual. I so move.

(The motion was seconded, put to a vote and carried.)

Mr. Zeeman: On page 5–34 is paragraph 3: "Permanent Monuments." This is part of the general heading "Maintenance of Line." Since you have just eliminated the first and second paragraphs, it is recommended that we delete paragraph 3 and convert the subheading on Permanent Monuments into a general heading over the text which it is proposed to retain. I so move.

(The motion was seconded, put to a vote and carried. Mr. Zeeman then submitted the revisions under the side heading "Page 5–42" on page 554 and extending to the middle of page 556.)

Mr. Zeeman: Your committee presents a new table on page 555, which is identical with the table now appearing in the Manual except that it does not refer to the term "maximum speed" but uses the two terms, as we show here, of *Se* which is the symbol for equilibrium speed, and *Sp* which is the symbol for permissible speed. As outlined in the accompanying paragraphs which we recommend for inclusion, this permissible speed is the speed at three inches unbalanced elevation. Nothing is said about that being the maximum speed or safe speed. It is just a comfortable speed or permissible speed.

I move that the revisions as shown on page 554 to the side heading "Page 5–44" on page 556, including the new table, 507, to replace the present table 507 now in the Manual, be adopted.

(The motion was seconded.)

President Hastings: Is there discussion?

(Mr. O. E. Selby, Cleveland, Cincinnati, Chicago & St. Louis, read the following discussion and submitted the three accompanying tables.)

This discussion relates to the recommendations as to revisions of pages 5–42 and 5–43 of the Manual.

In place of these recommendations, the following is offered:

Page 5–42

Delete the entire page and insert:

ELEVATIONS AND SPEEDS FOR CURVES

Elevation of Curves

The approximate formula:

$$e = \frac{Gv^2}{32.16\ R}$$

in which

$e =$ Elevation in feet,
$G =$ Distance between points of contact of wheel on rail,
$v =$ Velocity in feet per second,
$R =$ Radius of curve in feet,

will give the essentially correct equilibrium elevation for the outer rail of curves.

From the formula above may be derived the simpler formula,

$$E = \frac{DS^2}{1{,}500}$$

in which

$E =$ Elevation in inches of the outer rail,
$D =$ Degree of curve,
$S =$ Speed in miles per hour,

and from this the formula:

$$E = \frac{DS^2}{1{,}500} - 3,$$

will give 3-inch unbalanced speed elevations.

Insert also the matter in the Committee's recommendation appearing in the last paragraph on page 554 and five paragraphs on page 556, Bulletin 416.

Page 5–43

Delete the entire page, Table 507, and insert:

Table 507 Elevation of outer rail for permissible speeds
Table 508 Permissible speeds
Table 509 Elevation of outer rail for equilibrium speeds
Table 510 Equilibrium speeds

TABLE 1

ELEVATION OF OUTER RAIL — FOR — PERMISSIBLE SPEEDS

Elevations shown in inches, Speed in miles per hour

SPEED	DEGREE OF CURVE																						SPEED
	0°30′	0°40′	0°50′	1°00′	1°15′	1°30′	1°45′	2°00′	2°15′	2°30′	2°45′	3°00′	3°30′	4°	5°	6°	7°	8°	9°	10°	11°	12°	
20																						0¼	20
21																					0¼	0½	21
22																				0¼	0½	0⅞	22
23																			0⅛	0½	0⅞	1¼	23
24																		0⅛	0½	0⅞	1¼	1⅝	24
25																		0⅜	0¾	1⅛	1⅝	2	25
26																	0⅛	0⅝	1	1½	2	2⅜	26
27																	0⅜	0⅞	1⅜	1⅞	2⅜	2⅞	27
28																0⅛	0⅝	1⅛	1¾	2¼	2¾	3¼	28
29																0⅜	0⅞	1½	2	2⅝	3⅛	3¾	29
30																0⅝	1¼	1¾	2⅜	3	3⅝	4¼	30
31															0¼	0⅞	1½	2⅛	2¾	3⅜	4	4¾	31
32															0⅜	1⅛	1¾	2½	3⅛	3⅞	4½	5¼	32
33															0⅝	1⅜	2⅛	2¾	3½	4¼	5	5¾	33
34														0⅛	0⅞	1⅝	2⅜	3⅛	3⅞	4¾	5½	6¼	34
35														0¼	1⅛	1⅞	2¾	3½	4⅜	5⅛	6	6¾	35
36														0½	1⅜	2⅛	3	3⅞	4¾	5⅝	6½	7⅜	36
37													0¼	0⅝	1⅝	2½	3⅜	4¼	5¼	6⅛	7		
38													0⅜	0⅞	1⅞	2¾	3¾	4¾	5⅝	6⅝			
39													0½	1	2⅛	3⅛	4⅛	5⅛	6⅛	7⅛			
40												0¼	0¾	1¼	2⅜	3⅜	4½	5½	6⅝				
41											0⅛	0⅜	0⅞	1½	2⅝	3¾	4⅞	6	7⅛				
42											0¼	0½	1⅛	1¾	2⅞	4	5¼	6⅜					
43										0⅛	0⅜	0¾	1⅜	1⅞	3⅛	4⅜	5⅝	6⅞					
44										0¼	0½	0⅞	1½	2⅛	3½	4¾	6	7⅜					
45										0⅝	0¾	1	1¾	2⅜	3¾	5⅛	6½						
46									0⅛	0½	0⅞	1¼	1⅞	2⅝	4	5½	6⅞						
47									0⅜	0⅝	1	1⅜	2⅛	2⅞	4⅜	5⅞	7¼						
48								0⅛	0½	0⅞	1¼	1⅝	2⅜	3⅛	4⅝	6¼							
49								0¼	0⅝	1	1⅜	1¾	2⅝	3⅜	5	6⅝							
50								0⅜	0¾	1⅛	1⅝	2	2⅞	3⅝	5⅜	7							
51								0½	0⅞	1⅜	1¾	2¼	3⅛	3⅞	5⅝								
52							0⅛	0⅝	1	1½	2	2⅜	3¼	4¼	6								
53							0¼	0¾	1¼	1⅝	2⅛	2⅝	3½	4½	6⅜								
54							0⅜	0⅞	1⅜	1⅞	2⅜	2⅞	3¾	4¾	6¾								
55							0½	1	1½	2	2½	3	4	5⅛	7⅛								
56						0⅛	0⅝	1⅛	1¾	2¼	2¾	3¼	4⅜	5⅜									
57						0¼	0¾	1⅜	1⅞	2⅜	3	3½	4⅝	5⅝									
58						0⅜	0⅞	1½	2	2⅝	3⅛	3¾	4⅞	6									
59						0½	1	1⅝	2¼	2¾	3⅜	4	5⅛	6¼									
60						0⅝	1¼	1¾	2⅜	3	3⅝	4¼	5⅜	6⅝									
61					0⅛	0¾	1⅜	2	2⅝	3¼	3⅞	4½	5⅝	6⅞									
62					0¼	0⅞	1½	2⅛	2¾	3⅜	4	4¾	6	7¼									
63					0¼	1	1⅝	2¼	3	3⅝	4¼	5	6¼										
64					0⅜	1⅛	1¾	2½	3⅛	3⅞	4½	5¼	6½										
65					0½	1¼	1⅞	2⅝	3⅜	4	4¾	5½	6⅞										
66					0⅝	1⅜	2⅛	2¾	3½	4¼	5	5¾	7⅛										
67					0¾	1½	2¼	3	3¾	4½	5¼	6											
68				0⅛	0⅞	1⅝	2⅜	3⅛	3⅞	4¾	5½	6¼											
69				0⅛	1	1¾	2½	3⅜	4⅛	4⅞	5¾	6½											

SPEED	DEGREE OF CURVE												SPEED
	0°30′	0°40′	0°50′	1°00′	1°15′	1°30′	1°45′	2°00′	2°15′	2°30′	2°45′	3°0′	
70				0¼	1⅛	1⅞	2¾	3½	4⅜	5⅛	6	6¾	70
71				0⅜	1¼	2	2⅞	3¾	4½	5⅜	6¼	7⅛	71
72				0½	1⅜	2⅛	3	3⅞	4¾	5⅝	6½		
73				0½	1½	2⅜	3¼	4⅛	5	5⅞	6¾		
74				0⅝	1⅝	2½	3⅜	4¼	5¼	6⅛	7		
75			0⅛	0¾	1¾	2⅝	3⅝	4½	5½	6⅜			
76			0¼	0⅞	1⅞	2¾	3¾	4¾	5⅝	6⅝			
77			0¼	1	2	2⅞	3⅞	4⅞	5⅞	6⅞			
78			0⅜	1	2⅛	3⅛	4⅛	5⅛	6⅛	7⅛			
79			0½	1⅛	2¼	3¼	4¼	5⅜	6⅜				
80			0½	1¼	2⅜	3⅜	4½	5½	6⅝				
81			0⅝	1⅜	2½	3½	4⅝	5¾	6⅞				
82			0¾	1½	2⅝	3¾	4⅞	6	7⅛				
83			0⅞	1⅝	2¾	3⅞	5	6⅛					
84		0⅛	0⅞	1¾	2⅞	4	5¼	6⅜					
85		0¼	1	1⅞	3	4¼	5⅜	6⅝					
86		0¼	1⅛	1⅞	3⅛	4⅜	5⅝	6⅞					
87		0⅜	1¼	2	3¼	4⅝	5⅞	7⅛					
88		0½	1¼	2⅛	3½	4¾	6						
89		0½	1⅜	2¼	3⅝	4⅞	6¼						
90		0⅝	1½	2⅜	3¾	5⅛	6½						
91		0⅝	1⅝	2½	3⅞	5¼	6⅝						
92		0¾	1¾	2⅝	4	5½	6⅞						
93		0⅞	1¾	2¾	4¼	5⅝	7⅛						
94		0⅞	1⅞	2⅞	4⅜	5⅞							
95		1	2	3	4½	6							
96	0⅛	1⅛	2⅛	3⅛	4⅝	6¼							
97	0⅛	1⅛	2¼	3¼	4⅞	6⅜							
98	0¼	1¼	2⅜	3⅜	5	6⅝							
99	0¼	1⅜	2½	3½	5⅛	6¾							
100	0⅜	1½	2½	3⅝	5⅜	7							

$$E = \frac{S^2 D}{1500} - 3$$

E = Elevation in inches
S = Speed in miles per hour
D = Degree of Curve

Table 507.—Elevation of Outer Rail for Permissible Speeds.

The revision of page 5–42 here offered consists in a correction of the definition of *G* and the substitution of the simplified formula appearing in Proceedings, Vol. 40, page 174, for the one involving a coefficient of five decimal places.

The Track committee formula is based on the gage, 56–½ in., but it is well known that the gage is not the correct distance to be used in this formula. It should be the distance between the bearing points of wheels on rails. No one knows exactly what it is, but certainly it exceeds 56–½ in. The value 57.11 in. comes out of the formula here offered. It was not assumed but is merely the result of using the denominator 1,500 for simplicity. It is agreed that the exact distance is a minor matter and the simplicity of the formula using 1,500 in the denominator is sufficient to justify it.

The revised Table 507 proposed by the committee (page 5–43) has the single merit of greater legibility. It contains precisely the same quantities and retains all of the undesirable features of the old table. These features are cumbersomeness, crudity, and incompleteness.

The cumbersomeness consists in mixing the quantities for two kinds of speeds on alternate lines in one table, thus increasing the difficulty and liability to error in reading the table.

The crudity consists in giving speeds only in multiples of five miles per hour and those scattered in such a way as would make interpolation difficult.

$S^2 = \frac{1500}{D}(E+3)$

TABLE 2
PERMISSIBLE SPEEDS
Elevations shown in inches. Speed in miles per hour

S=Miles per hour
E=Elevation in inches
D=Degree of Curve

ELEV.	0°30'	0°40'	0°50'	1°0'	1°15'	1°30'	1°45'	2°0'	2°15'	2°30'	2°45'	3°0'	3°30'	4°0'	5°0'	6°0'	7°0'	8°0'	9°0'	10°0'	11°0'	12°0'	13°0'	14°0'	15°0'	16°0'	17°0'	18°0'	19°0'	20°0'	ELEV.
½"	102	89	79	72	65	59	55	51	48	46	44	42	39	36	32	30	27	26	24	23	22	21	20	19	19	18	18	17	17	16	½"
¾"	106	92	82	75	67	61	57	53	50	47	45	43	40	38	34	31	28	27	25	24	23	22	21	20	19	19	18	18	17	17	¾"
1"	110	95	85	77	69	63	59	55	52	49	47	45	41	39	35	32	29	27	26	24	23	22	21	21	20	19	19	18	18	17	1"
1¼"	113	98	87	80	71	65	60	56	53	50	48	46	43	40	36	33	30	28	27	25	24	23	22	21	21	20	19	19	18	18	1¼"
1½"	116	101	90	82	73	67	62	58	55	52	50	47	44	41	37	34	31	29	27	26	25	24	23	22	21	21	20	19	19	18	1½"
1¾"	119	103	92	84	75	69	64	60	56	53	51	49	45	42	38	34	32	30	28	27	25	24	23	23	22	21	20	20	19	19	1¾"
2"	122	106	95	87	77	71	65	61	58	55	52	50	46	43	39	35	33	31	29	27	26	25	24	23	22	22	21	20	20	19	2"
2¼"		109	97	89	79	72	67	63	59	56	54	51	47	44	40	36	34	31	30	28	27	26	25	24	23	22	22	21	20	20	2¼"
2½"		111	99	91	81	74	69	64	61	57	55	52	49	45	41	37	34	32	30	29	27	26	25	24	23	23	22	21	21	20	2½"
2¾"		114	102	93	83	76	70	66	62	59	56	54	50	46	42	38	35	33	31	29	28	27	26	25	24	23	23	22	21	21	2¾"
3"		116	104	95	85	77	72	67	63	60	57	55	51	47	42	39	36	34	32	30	29	27	26	25	24	24	23	22	22	21	3"
3¼"		119	106	97	87	79	73	68	65	61	58	56	52	48	43	40	37	34	32	31	29	28	27	26	25	24	23	23	22	22	3¼"
3½"		121	108	99	88	81	75	70	66	62	60	57	53	49	44	40	37	35	33	31	30	29	27	26	25	25	24	23	23	22	3½"
3¾"			110	101	90	82	76	71	67	64	61	58	54	50	45	41	38	36	34	32	30	29	28	27	26	25	24	24	23	23	3¾"
4"			112	102	92	84	77	72	68	65	62	59	55	51	46	42	39	36	34	32	31	30	28	27	26	26	25	24	24	23	4"
4¼"			114	104	93	85	79	74	70	66	63	60	56	52	47	43	39	37	35	33	31	30	29	28	27	26	25	25	24	23	4¼"
4½"			116	106	95	87	80	75	71	67	64	61	57	53	47	43	40	38	35	34	32	31	29	28	27	27	26	25	24	24	4½"
4¾"			118	108	96	88	81	76	72	68	65	62	58	54	48	44	41	38	36	34	33	31	30	29	28	27	26	25	25	24	4¾"
5"			120	110	98	89	83	77	73	69	66	63	59	55	49	45	41	39	37	35	33	32	30	29	28	27	27	26	25	24	5"
5¼"				111	99	91	84	79	74	70	67	64	59	56	50	45	42	39	37	35	34	32	31	30	29	28	27	26	26	25	5¼"
5½"				113	101	92	85	80	75	71	68	65	60	56	50	46	43	40	38	36	34	33	31	30	29	28	27	27	26	25	5½"
5¾"				115	102	94	87	81	76	72	69	66	61	57	51	47	43	41	38	36	35	33	32	31	30	29	28	27	26	26	5¾"
6"				116	104	95	88	82	77	73	70	67	62	58	52	47	44	41	39	37	35	34	32	31	30	29	28	27	27	26	6"
6¼"				118	105	96	89	83	79	74	71	68	63	59	53	48	45	42	39	37	36	34	33	31	30	29	29	28	27	26	6¼"
6½"				119	107	97	90	84	80	75	72	69	64	60	53	49	45	42	40	38	36	34	33	32	31	30	29	28	27	27	6½"
6¾"				121	108	99	91	86	81	76	73	70	65	60	54	49	46	43	40	38	36	35	34	32	31	30	29	29	28	27	6¾"
7"					110	100	93	87	82	77	74	71	65	61	55	50	46	43	41	39	37	35	34	33	32	31	30	29	28	27	7"

Table 508.—Permissible Speeds.

Manual material should be of sufficient scope and refinement to enable the engineer to use it as a tool in whatever design or instructions he may be engaged upon. In this case the design is that of a schedule of elevations, speeds and spirals for a given stretch of track and the instructions may be a set of standards or merely orders to the section foreman as to what to put on the speed-limit boards. Certainly a more refined tool than Table 507 is needed for all of these purposes except the last.

The incompleteness consists in not giving readily the elevation required for a given speed as well as the speed for a given elevation. It is true that the table gives both after a fashion, but it would not be of much help in an extended problem.

SPEED	DEGREE OF CURVE																						SPEED
	0°30'	0°40'	0°50'	1°	1°15'	1°30'	1°45'	2°	2°15'	2°30'	2°45'	3°	3°30'	4°	5°	6°	7°	8°	9°	10°	11°	12°	
10				0⅛	0⅛	0⅛	0⅛	0⅛	0⅛	0⅛	0⅛	0¼	0¼	0¼	0⅜	0⅜	0½	0½	0⅝	0⅝	0¾	0¾	10
11			0⅛	0⅛	0⅛	0⅛	0⅛	0⅛	0⅛	0¼	0¼	0¼	0¼	0⅜	0⅜	0½	0⅝	0⅝	0¾	0¾	0⅞	1	11
12		0⅛	0⅛	0⅛	0⅛	0⅛	0⅛	0¼	0¼	0¼	0¼	0¼	0⅜	0⅜	0½	0⅝	0⅝	0¾	0⅞	1	1	1⅛	12
13		0⅛	0⅛	0⅛	0⅛	0⅛	0¼	0¼	0¼	0¼	0¼	0⅜	0⅜	0½	0⅝	0⅝	0¾	0⅞	1	1⅛	1¼	1⅜	13
14	0⅛	0⅛	0⅛	0⅛	0⅛	0¼	0¼	0¼	0¼	0⅜	0⅜	0⅜	0½	0½	0⅝	0¾	0⅞	1	1⅛	1¼	1⅜	1⅝	14
15	0⅛	0⅛	0⅛	0⅛	0¼	0¼	0¼	0¼	0⅜	0⅜	0⅜	0½	0½	0⅝	0¾	0⅞	1	1¼	1⅜	1½	1⅝	1¾	15
16	0⅛	0⅛	0⅛	0⅛	0¼	0¼	0¼	0⅜	0⅜	0⅜	0½	0½	0⅝	0⅝	0⅞	1	1¼	1⅜	1½	1¾	1⅞	2	16
17	0⅛	0⅛	0⅛	0¼	0¼	0¼	0⅜	0⅜	0⅜	0½	0½	0⅝	0⅝	0¾	1	1⅛	1⅜	1½	1¾	1⅞	2⅛	2¼	17
18	0⅛	0⅛	0⅛	0¼	0¼	0⅜	0⅜	0⅜	0½	0½	0⅝	0⅝	0¾	0⅞	1⅛	1¼	1½	1¾	2	2⅛	2⅜	2⅝	18
19	0⅛	0⅛	0¼	0¼	0¼	0⅜	0⅜	0½	0½	0⅝	0⅝	0¾	0⅞	1	1¼	1½	1⅝	1⅞	2⅛	2⅜	2⅝	2⅞	19
20	0⅛	0⅛	0¼	0¼	0⅜	0⅜	0½	0½	0⅝	0⅝	0¾	0¾	0⅞	1⅛	1⅜	1⅝	1⅞	2⅛	2⅜	2⅝	2⅞	3¼	20
21	0⅛	0¼	0¼	0¼	0⅜	0½	0½	0⅝	0⅝	0¾	0¾	0⅞	1	1⅛	1½	1¾	2	2⅜	2⅝	3	3¼	3½	21
22	0⅛	0¼	0¼	0⅜	0⅜	0½	0⅝	0⅝	0¾	0¾	0⅞	1	1⅛	1¼	1⅝	1⅞	2¼	2⅝	2⅞	3¼	3½	3⅞	22
23	0⅛	0¼	0¼	0⅜	0½	0½	0⅝	0¾	0¾	0⅞	1	1	1¼	1⅜	1¾	2⅛	2½	2⅞	3⅛	3½	3⅞	4¼	23
24	0¼	0¼	0⅜	0⅜	0½	0⅝	0⅝	0¾	0⅞	1	1	1⅛	1⅜	1½	1⅞	2¼	2¾	3⅛	3½	3⅞	4¼	4⅝	24
25	0¼	0¼	0⅜	0⅜	0½	0⅝	0¾	0⅞	1	1	1⅛	1¼	1½	1⅝	2⅛	2½	2⅞	3⅜	3¾	4⅛	4⅝	5	25
26	0¼	0¼	0⅜	0½	0⅝	0⅝	0¾	0⅞	1	1⅛	1¼	1⅜	1⅝	1¾	2¼	2¾	3⅛	3⅝	4	4½	5	5⅜	26
27	0¼	0⅜	0⅜	0½	0⅝	0¾	0⅞	1	1⅛	1¼	1⅜	1½	1¾	2	2⅜	2⅞	3⅜	3⅞	4⅜	4⅞	5⅜	5⅞	27
28	0¼	0⅜	0⅜	0½	0⅝	0¾	0⅞	1	1⅛	1¼	1⅜	1⅝	1⅞	2⅛	2⅝	3⅛	3⅝	4⅛	4¾	5¼	5¾	6¼	28
29	0¼	0⅜	0½	0½	0¾	0⅞	1	1⅛	1¼	1⅜	1½	1⅝	2	2¼	2¾	3⅜	3⅞	4½	5	5⅝	6⅛	6¾	29
30	0¼	0⅜	0½	0⅝	0¾	0⅞	1	1¼	1⅜	1½	1⅝	1¾	2⅛	2⅜	3	3⅝	4¼	4¾	5⅜	6	6⅝	7¼	30
31	0⅜	0⅜	0½	0⅝	0¾	1	1⅛	1¼	1½	1⅝	1¾	1⅞	2¼	2⅝	3¼	3⅞	4½	5⅛	5¾	6⅜	7		
32	0⅜	0½	0⅝	0⅝	0⅞	1	1¼	1⅜	1½	1¾	1⅞	2	2⅜	2¾	3⅜	4⅛	4¾	5½	6⅛	6⅞			
33	0⅜	0½	0⅝	0¾	0⅞	1⅛	1¼	1½	1⅝	1⅞	2	2⅛	2½	2⅞	3⅝	4⅜	5⅛	5¾	6½	7¼			
34	0⅜	0½	0⅝	0¾	1	1⅛	1⅜	1½	1¾	1⅞	2⅛	2¼	2¾	3⅛	3⅞	4⅝	5⅜	6⅛	6⅞				
35	0⅜	0½	0⅝	0⅞	1	1¼	1⅜	1⅝	1⅞	2	2¼	2½	2⅞	3¼	4⅛	4⅞	5¾	6½	7⅜				
36	0⅜	0⅝	0¾	0⅞	1⅛	1¼	1½	1¾	2	2⅛	2⅜	2⅝	3	3½	4⅜	5⅛	6	6⅞					
37	0½	0⅝	0¾	0⅞	1⅛	1⅜	1⅝	1⅞	2	2¼	2½	2¾	3¼	3⅝	4⅝	5½	6⅜	7¼					
38	0½	0⅝	0¾	1	1¼	1½	1⅝	1⅞	2⅛	2⅜	2⅝	2⅞	3⅜	3⅞	4⅞	5¾	6¾						
39	0½	0⅝	0⅞	1	1¼	1½	1¾	2	2¼	2½	2¾	3	3½	4	5⅛	6⅛	7⅛						
40	0½	0¾	0⅞	1⅛	1⅜	1⅝	1⅞	2⅛	2⅜	2⅝	2⅞	3¼	3¾	4¼	5⅜	6⅜							
41	0½	0¾	0⅞	1⅛	1⅜	1⅝	2	2¼	2½	2¾	3⅛	3⅜	3⅞	4½	5⅝	6¾							
42	0⅝	0¾	1	1⅛	1½	1¾	2	2⅜	2⅝	3	3¼	3½	4⅛	4¾	5⅞	7							
43	0⅝	0⅞	1	1¼	1½	1⅞	2⅛	2½	2¾	3⅛	3⅜	3¾	4⅜	4⅞	6⅛								
44	0⅝	0⅞	1⅛	1¼	1⅝	1⅞	2¼	2⅝	2⅞	3¼	3½	3⅞	4½	5⅛	6½								
45	0⅝	0⅞	1⅛	1⅜	1¾	2	2⅜	2¾	3	3⅜	3¾	4	4¾	5⅜	6¾								
46	0¾	1	1⅛	1⅜	1¾	2⅛	2½	2⅞	3⅛	3½	3⅞	4¼	4⅞	5⅝	7								
47	0¾	1	1¼	1½	1⅞	2¼	2⅝	3	3⅜	3⅝	4	4⅜	5⅛	5⅞									
48	0¾	1	1¼	1½	1⅞	2¼	2¾	3⅛	3½	3⅞	4¼	4⅝	5⅜	6⅛									
49	0¾	1⅛	1⅜	1⅝	2	2⅜	2¾	3¼	3⅝	4	4⅜	4¾	5⅝	6⅜									
50	0⅞	1⅛	1⅜	1⅝	2⅛	2½	2⅞	3⅜	3¾	4⅛	4⅝	5	5⅞	6⅝									
51	0⅞	1⅛	1½	1¾	2⅛	2⅝	3	3½	3⅞	4⅜	4¾	5¼	6⅛	6⅞									
52	0⅞	1¼	1½	1¾	2¼	2¾	3⅛	3⅝	4	4½	5	5⅜	6¼	7¼									
53	0⅞	1¼	1½	1⅞	2⅜	2¾	3¼	3¾	4¼	4⅝	5⅛	5⅝	6½										
54	1	1¼	1⅝	2	2⅜	2⅞	3⅜	3⅞	4⅜	4⅞	5⅜	5⅞	6¾										
55	1	1⅜	1⅝	2	2½	3	3½	4	4½	5	5½	6	7										
56	1	1⅜	1¾	2⅛	2⅝	3⅛	3⅝	4⅛	4¾	5¼	5¾	6¼											
57	1⅛	1½	1¾	2⅛	2¾	3¼	3¾	4⅜	4⅞	5⅜	6	6½											
58	1⅛	1½	1⅞	2¼	2¾	3⅜	3⅞	4½	5	5⅝	6⅛	6¾											
59	1⅛	1½	1⅞	2⅜	2⅞	3½	4	4⅝	5¼	5¾	6⅜	7											

SPEED	DEGREE OF CURVE											SPEED
	0°30'	0°40'	0°50'	1°	1°15'	1°30'	1°45'	2°	2°15'	2°30'	2°45'	
60	1¼	1⅝	2	2⅜	3	3⅝	4¼	4¾	5⅜	6	6⅝	60
61	1¼	1⅝	2⅛	2½	3⅛	3¾	4⅜	5	5⅝	6¼	6⅞	61
62	1¼	1¾	2⅛	2⅝	3¼	3⅞	4½	5⅛	5¾	6⅜	7	62
63	1⅜	1¾	2¼	2⅝	3¼	4	4⅝	5¼	6	6⅝		
64	1⅜	1⅞	2¼	2¾	3⅜	4⅛	4¾	5½	6⅛	6⅞		
65	1⅜	1⅞	2⅜	2⅞	3½	4¼	4⅞	5⅝	6⅜	7		
66	1½	1⅞	2⅜	2⅞	3⅝	4⅜	5⅛	5¾	6½			
67	1½	2	2½	3	3¾	4½	5¼	6	6¾			
68	1½	2	2⅝	3⅛	3⅞	4⅝	5⅜	6⅛	6⅞			
69	1⅝	2⅛	2⅝	3⅛	4	4¾	5½	6⅜	7⅛			
70	1⅝	2⅛	2¾	3¼	4⅛	4⅞	5¾	6½				
71	1⅝	2¼	2¾	3⅜	4¼	5	5⅞	6¾				
72	1¾	2¼	2⅞	3½	4⅜	5⅛	6	6⅞				
73	1¾	2⅜	3	3½	4½	5⅜	6¼	7⅛				
74	1⅞	2⅜	3	3⅝	4⅝	5½	6⅜					
75	1⅞	2½	3⅛	3¾	4¾	5⅝	6⅝					
76	1⅞	2⅝	3¼	3⅞	4⅞	5¾	6¾					
77	2	2⅝	3¼	4	5	5⅞	6⅞					
78	2	2¾	3⅜	4	5⅛	6⅛	7⅛					
79	2⅛	2¾	3½	4⅛	5¼	6¼						
80	2⅛	2⅞	3½	4¼	5⅜	6⅜						
81	2⅛	2⅞	3⅝	4⅜	5½	6½						
82	2¼	3	3¾	4½	5⅝	6¾						
83	2¼	3	3⅞	4⅝	5¾	6⅞						
84	2⅜	3⅛	3⅞	4¾	5⅞	7						
85	2⅜	3¼	4	4⅞	6							
86	2½	3¼	4⅛	4⅞	6⅛							
87	2½	3⅜	4¼	5	6¼							
88	2⅝	3½	4¼	5⅛	6½							
89	2⅝	3½	4⅜	5¼	6⅝							
90	2¾	3⅝	4½	5⅜	6¾							
91	2¾	3⅝	4⅝	5½	6⅞							
92	2⅞	3¾	4¾	5⅝	7							
93	2⅞	3⅞	4¾	5¾								
94	3	3⅞	4⅞	5⅞								
95	3	4	5	6								
96	3⅛	4⅛	5⅛	6⅛								
97	3⅛	4⅛	5¼	6¼								
98	3¼	4¼	5⅜	6⅜								
99	3¼	4⅜	5½	6½								
100	3⅜	4½	5½	6⅝								

ELEVATION OF OUTER RAIL
FOR
EQUILIBRIUM SPEEDS

Elevations shown in inches, Speed in miles per hour

$E = \frac{DS^2}{1500}$

E = Elevation in inches
S = Speed in miles per hour
D = Degree of Curve

Table 509.—Elevation of Outer Rail for Equilibrium Speeds.

Of the tables here offered, 507 and 508 are in Proceedings, Volume 40, Tables 1 and 2 following page 174. Tables 509 and 510 are merely the same thing extended to equilibrium speeds. It is not expected that the tables would be promulgated in this form by any one railroad, but they may be made the basis of standards or be of use in any problems involving the necessarily related features of curves, elevation, speeds and spirals.

President Hastings: It seems to the Chair that it is well nigh hopeless to get a vote from the convention on a matter of this kind, as technical and involved as it is. I am just wondering if the Track committee would be willing to have this entire subject

$S^2 = \frac{1500E}{D}$

S = Speed in miles per hour
E = Elevation in inches
D = Degree of Curve

EQUILIBRIUM SPEEDS

Elevation (Inches)	DEGREE OF CURVE																														Elevation (inches)
	0°30'	0°40'	0°50'	1°	1°15'	1°30'	1°45'	2°	2°15'	2°30'	2°45'	3°	3°30'	4°	5°	6°	7°	8°	9°	10°	11°	12°	13°	14°	15°	16°	17°	18°	19°	20°	
½	39	34	30	27	24	22	21	19	18	17	17	16	15	14	12	11	10	10	9	9	8	8	8	7	7	7	7	6	6	6	½
¾	47	41	37	34	30	27	25	24	22	21	20	19	18	17	15	14	13	12	11	11	10	10	9	9	8	8	8	8	8	8	¾
1	55	47	42	39	35	32	29	27	26	24	23	22	21	19	17	16	15	14	13	12	12	11	11	10	10	10	9	9	9	9	1
¼	61	53	47	43	39	35	33	31	29	27	26	25	23	22	19	18	16	15	14	14	13	13	12	12	11	11	10	10	10	10	¼
½	67	58	52	47	42	39	36	34	32	30	29	27	25	24	21	19	18	17	16	15	14	14	13	13	12	12	12	11	11	11	½
¾	72	63	56	51	46	42	39	36	34	32	31	30	27	26	23	21	19	18	17	16	15	15	14	14	13	13	12	12	11	11	¾
2	77	67	60	55	49	45	41	39	37	35	33	32	29	27	24	22	21	19	18	17	17	16	15	15	14	14	13	13	13	12	2
¼	82	71	64	58	52	47	44	41	39	37	35	34	31	29	26	24	22	21	19	18	18	17	16	16	15	15	14	14	13	13	¼
½	87	75	67	61	55	50	46	43	41	39	37	35	33	31	27	25	23	22	20	19	18	18	17	16	16	15	15	14	14	14	½
¾	91	79	70	64	57	52	49	45	43	41	39	37	34	32	29	26	24	23	21	20	19	19	18	17	17	16	16	15	15	14	¾
3	95	82	73	67	60	55	51	47	45	42	40	39	36	34	30	27	25	24	22	21	20	19	19	18	17	17	16	16	15	15	3
¼	99	86	76	70	62	57	53	49	47	44	42	40	37	35	31	29	26	25	23	22	21	20	19	19	18	17	17	16	16	16	¼
½	102	89	79	72	65	59	55	51	48	46	44	42	39	36	32	30	27	26	24	23	22	21	20	19	19	18	18	17	17	16	½
¾	106	92	82	75	67	61	57	53	50	47	45	43	40	38	34	31	28	27	25	24	23	22	21	20	19	19	18	18	17	17	¾
4	110	95	85	77	69	63	59	55	52	49	47	45	41	39	35	32	29	27	26	24	23	22	21	21	20	19	19	18	18	17	4
¼	113	98	87	80	71	65	60	56	53	50	48	46	43	40	36	33	30	28	27	25	24	23	22	21	21	20	19	19	18	18	¼
½	116	101	90	82	73	67	62	58	55	52	50	47	44	41	37	34	31	29	27	26	25	24	23	22	21	21	20	19	19	18	½
¾	119	103	92	84	75	69	64	60	56	53	51	49	45	42	38	34	32	30	28	27	25	24	23	23	22	21	20	20	19	19	¾
5	122	106	95	87	77	71	65	61	58	55	52	50	46	43	39	35	33	31	29	27	26	25	24	23	22	22	21	20	20	19	5
¼		109	97	89	79	72	67	63	59	56	54	51	47	44	40	36	34	31	30	28	27	26	25	24	23	22	22	21	20	20	¼
½		111	99	91	81	74	69	64	61	57	55	52	49	45	41	37	34	32	30	29	27	26	25	24	23	23	22	21	21	20	½
¾		114	102	93	83	76	70	66	62	59	56	54	50	46	42	38	35	33	31	29	28	27	26	25	24	23	23	22	21	21	¾
6		116	104	95	85	77	72	67	63	60	57	55	51	47	42	39	36	34	32	30	29	27	26	25	24	24	23	22	22	21	6
¼		119	106	97	87	79	73	68	65	61	58	56	52	48	43	40	37	34	32	31	29	28	27	26	25	24	23	23	22	22	¼
½		121	108	99	88	81	75	70	66	62	60	57	53	49	44	40	37	35	33	31	30	29	27	26	25	25	24	23	23	22	½
¾			110	101	90	82	76	71	67	64	61	58	54	50	45	41	38	36	34	32	30	29	28	27	26	25	24	24	23	23	¾
7			112	102	92	84	77	72	68	65	62	59	55	51	46	42	39	36	34	32	31	30	28	27	26	26	25	24	24	23	7

Table 510.—Equilibrium Speeds.

referred back. I understand that the subcommittees of the Track committee and of Committee 16—Economics of Railway Location and Operation have had a number of meetings, and they did not get together on certain features in connection with this matter of superelevation. I cannot see how the convention can intelligently vote or select what they want from the presentations, with one printed and the other presented to us here in discussion so that you cannot have it immediately before you when you give it consideration. You know, when the doctors disagree, there isn't very much hope for the patient. We have two doctors in this matter. The Track committee is one doctor, and the Committee on Economics of Railway Location and Operation is the other doctor.

Would the committee be willing to give consideration to this matter, or do you desire to bring the matter to a conclusion right here on the floor?

Chairman Arn: I think it would be very difficult to vote intelligently on it. Some of the members of the subcommittee of the Track committee were agreeable to some of these changes; the bulk of the members of the committee, as a whole were not. I might state that some of them couldn't see, for instance, why a change of about one percent of the gage distance used should make it necessary to change the material that is in the Manual, which has been in there and proven for many years. There were other points. It would look as if the best way to settle the matter is to refer it back to the committee.

President Hastings: The Chair is going to ask the committee to think it over between now and the time we convene this afternoon. We are going to have to break off the discussion at this point.

(The discussion was resumed after the luncheon recess.)

Mr. Zeeman: As the committee understands it, the criticism of the report as submitted seems to be mainly a question of theoretical detail. In the first place, Mr. Selby mentioned the difference between the formula that has been in the Manual for many years and the formula submitted, I believe, in a report of Committee 16 last year. The only difference in those two formulas is the value adopted for gage which has always been considered as 56–½ in., whereas it is proposed that 57.11 will be more nearly correct. As has been pointed out, the difference in the answer is less than one percent, and we feel that 56–½ in. is the proper distance to be used.

The next point that was brought up, I believe, was the fact that the table that we propose is not very plain, also that there were vacant spaces in it. We feel that the table as proposed, rounding off speeds in multiples of five miles an hour is about as close as is necessary for practical operation. We believe that most of the new speed boards are used in multiples of five miles an hour.

The next point I believe Mr. Selby mentioned was the substitution for one table which we call 507, of four other tables. The first one of these tables, as I remember it, is a table giving speeds for an unbalanced elevation of three inches. The second table is also based on three inches unbalanced elevation. The other two are tables that are used also in the determination of the length of spirals, which we feel do not belong in the subject under question.

We feel that one table giving both the speed for equilibrium elevation as well as the speed for three inches unbalanced elevation will answer all practical purposes.

Mr. Selby: The two tables relating to equilibrium speed are not intended to be used in merely establishing the length of spiral. That is a misconception. They are for information and convenient use in considering the problem before the man who is arranging the elevation.

As to the difference between the 56–½ and 57-and-a-fraction inches there is no practical difference in the results. I have compared Table 507 proposed by the committee and find it correct in all respects. It checks with the computation by the simplified formula proposed in this discussion.

I also had an opportunity to compare the results of the two formulas. In one case, the table computed to the nearest mile, of 174 comparable quantities, 90 checked exactly, 79 checked within one mile and only 5 showed differences of as much as two miles.

In view of the contention of the committee that the nearest five miles is sufficient, I submit that that is practically accurate.

Mr. V. T. Boughton (Plainfield, N. J.): As I understand the situation, the two collaborating subcommittees came to an agreement on this subject; then, when the report of the collaborating subcommittees came up, the main committee apparently scrapped the report of the collaborating committees. So that the collaborating committee from Committee 16 had nothing to do with the final report that comes to us, as showing they collaborated in that report. In view of that situation, it seems to me that the only thing for this organization to do is to refer this back to the committee to bring in a new report next year.

President Hastings: Does the committee wish to make any statement with reference to that suggestion?

Mr. Zeeman: No sir, the collaboration between the two committees was not on this subject. That only applied to the subject of spirals. In other words, there was no collaboration between this committee and Committee 16 on this particular subject of the revision of the Manual which only takes care of elevation on curves and speed on curves.

President Hastings: The material on spirals was presented by Mr. Baldridge this morning and was approved.

Mr. Boughton: Is it not true that these two subjects are so closely interrelated, you really can't handle one without handling the other? The whole matter ought to go back to the committee.

President Hastings: Does the chairman of the committee wish to make a statement?

Mr. Zeeman: This particular committee reports on speeds for curves and has nothing to do with the subject of the proper spiral for curves. That is why we object to the introduction in this report of the tables which were suggested, which have to do with spirals, because spirals have been disposed of.

Mr. Selby: I admit that the matter offered here by me has nothing to do with spirals and is not the product of the collaborating committees. I am agreeable to having the matter now before the house referred back to the committee, and I hope that Mr. Zeeman will withdraw his motion. If not, I desire to offer as an amendment to the motion the matter read before luncheon. I make such a motion.

(The amendment was seconded.)

President Hastings: You gentlemen are in a very difficult position. It has not been before you in written form. However, the Chair must recognize the fact that there is an amendment to the original motion, and it has been seconded. The proper procedure is to vote on the amendment.

Mr. F. L. C. Bond (Canadian National): Do I understand that this amendment calls upon us to approve something we haven't seen?

President Hastings: That is exactly what it does.

Mr. L. J. Hughes (Chicago, Rock Island & Pacific): I should like to ask the committee if this written discussion was received by the committee, and did the committee have sufficient time to discuss it and give it consideration. After considering same, was it the opinion of the committee that the matter should be incorporated in their report? That is the information that I am requesting before I vote on this proposed amendment.

Mr. Zeeman: In reply to Mr. Hughes I can say that this matter was not submitted to the committee.

Vice-President Fanning (from the floor): The rules for publication state that any amendment to material presented for the Manual, which affects underlying principles, if adopted, shall of itself constitute a recommital of such part of the report as the committee considers affected. So, I do not believe that a substantial amendment to a committee report offered for the Manual can be made here. The only action that this convention can take is to accept the report or refer it back to the committee.

President Hastings: I believe that the point of order is well taken, and the Chair rules that the amendment, because of its scope, is out of order. We return to a vote on the original motion. Are you ready for that question which is for the approval of the material which was presented by the committee?

Mr. Selby: I will offer an amendment to refer this subject back to the committee.

(The amendment was seconded, put to a vote and lost.)

President Hastings: We return to the vote on the original motion for the adoption of the material as presented. Are you ready for that question?

Chairman Arn: While the subcommittee did not have this matter to pass upon at the subcommittee meeting, every point that is involved in the matter submitted by Mr. Selby was discussed at the general meeting of the committee which approved the subcommittee reports as they are now published, and a vote was taken on every one of them, and a majority of the Track committee was in favor of the matter as now in the Bulletin.

(The motion was then put to a vote and carried.)

Mr. Zeeman: The next item refers to page 5–44. The committee proposes to delete the six paragraphs, down to Sub-title 2 and make the sub-title reading "Vertical Curves" a general title covering the text which follows. There is no change whatever in the text that follows. I so move.

(The motion was seconded, put to a vote and carried.)

Mr. Zeeman: Page 5–46, the general heading now in the Manual covers the subject "Maintenance of Gage" followed by Sub-title 1, Appliances and Methods Used To Prevent Spreading of Track, followed in turn by the recommendation that tie plates with shoulders be used, and also that, when no tie plates are used, the outside of the rail shall be double-spiked. We consider that superfluous and recommend that it be deleted from the Manual.

On the same page is Sub-title "2. General." Because of the deletion just approved we recommend this title be changed to read "Gage."

On the same page, at the bottom is a note that refers to the Portfolio of AREA Trackwork Plans for data on gages and flangeways on curves. As this is already covered in the Table of Contents of the chapter we recommend that the note be deleted from this particular page. I move the adoption of the recommendations with respect to page 5–46.

(The motion was seconded, put to a vote and carried.)

Mr. Zeeman: The last item relates to page 44 of the Glossary. The committee recommends the deletion of the definition of the term "Spur" because a definition of "Spur" appears on page 50, tied into Committee 14, which is better than the definition given for the Track committee. I so move.

(The motion was seconded, put to a vote and carried.)

Chairman Arn: That completes the report of the Track committee.

President Hastings: This is a hard-working committee. I have said a good deal about different committees in the last couple of days, but I would like to say something about this one, too. They have had a pretty hard job. They accomplished a great deal in the year's work but they had a pretty good sized group of men to work with. We are expecting even more from them next year.

The Association thanks you, Colonel Arn, for what you and your committee have done and are doing and the fine work we expect you to do. You are excused with the thanks of this Association. (Applause)

MONOGRAPHS

Design of Connection Angles for Stringers of Railway Bridges

By Professor Wilbur M. Wilson
Research Professor of Structural Engineering, University of Illinois

Statement of Problem

The stringers of through-truss railway bridges are attached to the floor beams by means of connection angles.[1] The primary function of these connection angles is to transmit the end shear from the stringer to the floor beam but, because they are riveted to both the stringer and the floor beam, the angles are subjected to flexural stresses due to the deformation of other parts of the structure. There are two actions that contribute to these flexural stresses, as follows:

1. The bottom chord of the truss changes in length due to a change in the chord stress resulting from the passage of a train. There is not a corresponding change in the length of the stringers and, since the floor beam is connected to both the chord and the stringers, the floor beam is subjected to a transverse horizontal flexure which produces in each stringer an axial force which is repeated or reversed and which is transmitted through the connection angles. The magnitude of the force depends upon the magnitude of the change in the chord stress, on the stiffness of the floor beams, on the distance between stringer expansion joints, on the traction truss, and on the stiffness of connection angles.

2. The stringers deflect vertically because of the wheel loads and this deflection rotates the end of the stringer and subjects the connection to a flexural moment in the plane of the stringer web.

The effect of the elongation of the bottom chord of a through-truss bridge is to bend the outstanding legs of the connection angles, as shown in Fig. 1, over their entire depth. In general, there is one complete stress cycle for each passage of a train. The deflection of the stringer bends the outstanding leg of the connection angles at the top but the deflection decreases as the distance from the top of the angle increases. There is one complete cycle for the passage of each car truck.

There are three features relative to the flexure in the outstanding legs of the connection angles that are worthy of attention. (1) The flexural stress in the angles varies from near zero to a maximum a large number of times during the life of a bridge so that the problem is one of fatigue. (2) The flexural stress in the angles is incidental and contributes little, if any, to the support of the load so that if the connection were so constructed as to permit the movement without producing stress, the primary function of the connection would not be impaired. (3) The force that bends the outstanding legs of the angles and that is parallel to the axis of the rivets, fluctuates. But, because of the initial tension in the rivets, this fluctuating force produces but little fluctuation in the axial stress in the rivets. It probably does produce a fluctuating bending moment in the rivet due to the flexure of the outstanding leg of the connection angles, as shown in Fig. 1.

The floor frame of a bridge is a statically indeterminate structure with connections of unknown stiffness. For this reason an exact analysis of the frame cannot be made. It is believed to be possible, however, to set up assumptions on which to base an analysis which will give results accurate enough for purposes of design. These assumptions and the action of the floor frame are discussed in the following paragraphs.

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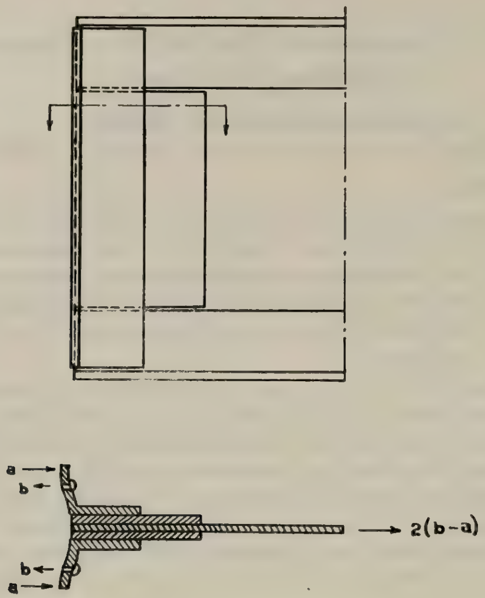
[1] The same is true of through plate-girder spans, although girder spans are not included in this discussion.



Deflection due to change in chord stress is uniform over entire length of connection angle.

Deflection due to flexure of stringer is a maximum at the top and decreases toward the center.

FIG. 1.—Flexure of Connection Angles for Stringers.

The magnitude of the stress in the outstanding leg of the connection angles due to a given deflection can only be computed if the degree of restraint at the toe and root of the leg is known or assumed. Recent fatigue tests of connection angles have been made[2] on the type of joint shown in Fig. 2. The specimen was subjected to an axial force, as shown at the top of the figure, and the force varied from zero to tension and back to zero for each cycle of a test. The fatigue strength was taken as the maximum stress during the cycle that would cause failure at 2,000,000 repetitions. Some specimens were designed to fail in the angles, others in the rivets. The deflection of the angles during a cycle was measured on the gage lines shown in Fig. 3, the machine being cranked by hand while the readings were taken. The results of these tests indicated that, for loads below the load corresponding to the fatigue strength of the connection, the measured and computed values of both the flexural stress and the deflection were very nearly equal if the computations were based on the assumption that the outstanding legs of the angles were restrained as shown in Fig. 4. As a result of these tests, all computed values of the deflection and of the flexural stress in the connection angles given in this discussion have been based upon the assumption that the angles were restrained as shown in that figure.

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[2] University of Illinois Engineering Experiment Station Bulletin No. 317.

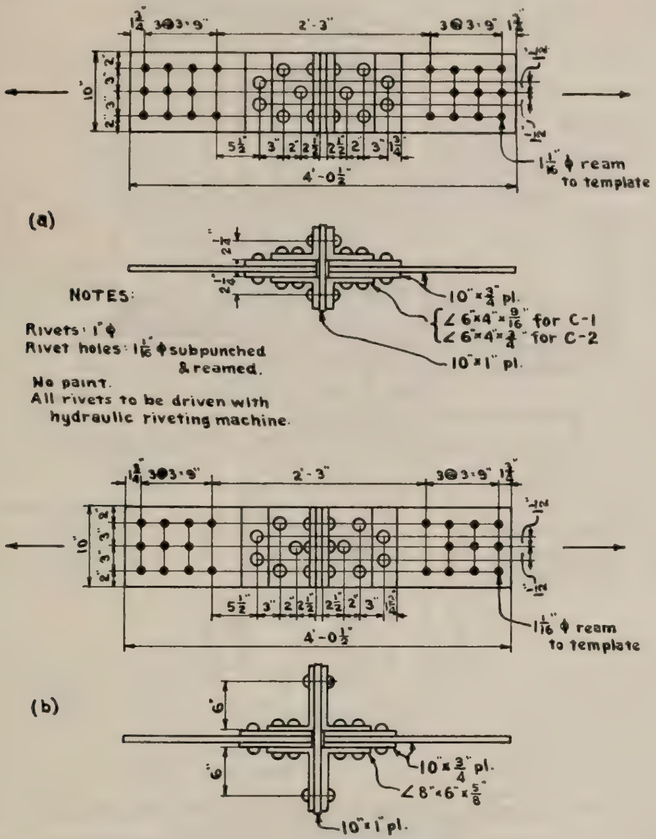

FIG. 2.—Details of Specimens.

There is a division of opinion among engineers relative to the motion between the end of the stringer web and the adjacent floor-beam web, the motion being a rotation in the plane of the stringer web. Some engineers contend that the center of rotation is at mid-depth of the stringer, others that it is near the bottom. The analyses of the connections presented in this report have been made on the assumption that the center of rotation is at mid-depth.

Stresses in structures are of two kinds, those due to loads and those due to deformations. These have been designated as load stresses and deformation stresses. A load stress in a statically determinate structure is not affected by the deformation of the structure[8] and the stress varies directly with the load up to failure. A deformation stress is due solely to deformation and varies directly with the deformation up to the proportional limit but no further. Because steel has a well-defined yield point, a deformation many times greater than the elastic deformation at the yield point can take place without producing a deformation stress appreciably greater than the yield-point stress.

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[8] This is true only if the minor effect of secondary stresses upon primary stresses is neglected. Secondary stresses as usually defined are deformation stresses.

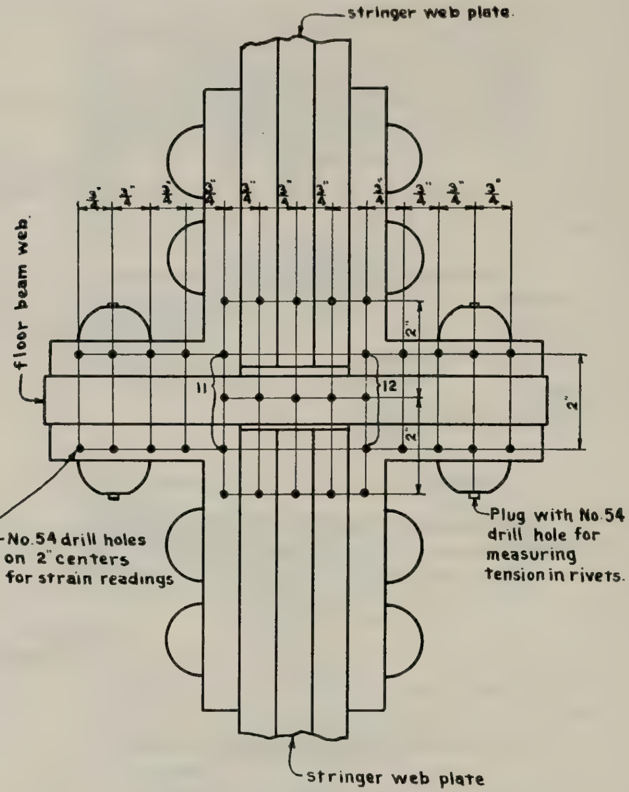
stringer web plate
3/4"
3/4"
3/4"
3/4"
3/4"
3/4"
3/4"
3/4"
3/4"
3/4"
3/4"
3/4"
floor beam web
2"
11
12
2"
2"
No.54 drill holes on 2" centers for strain readings
Plug with No.54 drill hole for measuring tension in rivets.
stringer web plate

Fig. 3.—Typical Layout of Strain-Gage Holes and Plugs for Measuring Tension in Rivets.

For this reason, deformation stresses and load stresses are not additive above the yield point. Moreover, fatigue tests show that structural steel can be stressed beyond the yield point several thousand times without failure.[4] It is believed that these facts explain why structural parts subjected to frequent repetitions of deformation stresses remain in service many years without failure even though the computed deformation greatly exceeds the elastic deformation at the yield point stress. The flexural stresses in connection angles are deformation stresses.

Deflection of Outstanding Legs of the Connection Angles Due to the Deflection of the Stringer

A deflection of the outstanding legs of the connection angles is caused by the shortening of the compression flange and the lengthening of the tension flange of the stringers. The magnitude of these movements depends upon: (1) The length of the stringer span; (2) the average stress along the flange on two adjacent spans, and (3) the ability of the connection to resist flexural moment in the plane of the stringer web. The depth

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[4] This statement is in no way contrary to the statement that a stress considerably below the yield point will cause failure after a larger number of repetitions.

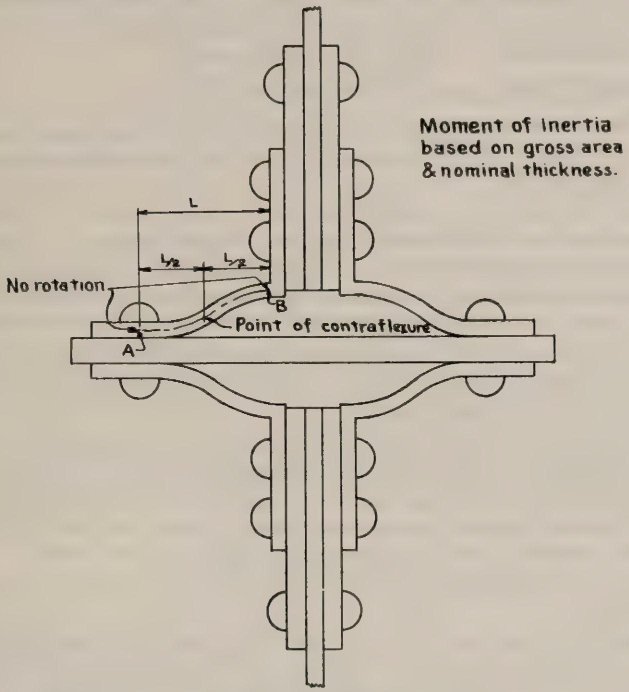

FIG. 4.—Assumed Action of Angles Used in Computing Flexural Stress and Deflection.

of the stringer affects the action of the connection angles indirectly but, because the deflection of the outstanding legs of the connection angles depends upon the shortening of the compression flange and the lengthening of the tension flange of the stringer and because these depend only upon the span length and the average stress over the length, the depth of the stringer as such does not need to be considered. The length of the stringer span affects the deflection of the outstanding leg of the connection angles because, for a given average flange stress, the change in length of a flange varies directly with its length.

The load upon both of two adjacent stringer spans affects the deflection of the outstanding legs of the connection angles because the stiffness of a floor beam to resist torque about its longitudinal gravity axis is relatively small and the web of the floor beam rotates with the connection angles of the stringers. The deflection of the outstanding leg of the connection angles will, therefor, depend upon the average flange stress over the two spans adjacent to the one floor beam. This is somewhat less than the maximum value of the average flange stress over one span because two adjacent stringer spans are not subjected to their maximum moments simultaneously.

A method of computing the deflection of the connection angles due to the deflection of the stringers is illustrated by the following numerical problem:

A recently constructed railway bridge consists of double-track, through-truss spans having 12 panels each 41 ft. 1½ in. long. Each stringer consists of one 70-in. by ⅜-in. web plate and four 8-in. by 6-in. by ¾-in. flange angles.

The analysis is based upon the following assumptions:

1. The center of rotation of the connection is at mid-depth.
2. The restraint of the outstanding legs of the connection angles is as shown in Fig. 4.

The dead-load stress, being constant, has practically no effect upon fatigue and will be neglected. Its value is 1,220 lb. per sq. in. The maximum fluctuation in the flange stress on a section through the rivet holes and at a point in the span where the live-load and impact stresses are a maximum is therefore 18,000 — 1,220, or 16,780 lb. per sq. in.

Computations based on a Cooper's loading show that the maximum value of the average simultaneous stresses along a flange is about 92 percent as great for two adjacent 41-ft. spans as it is for a single span.

For the loading that produces the maximum stress in a stringer span, the average stress is approximately two-thirds of the maximum stress. The ratio of the average stress along the flange to the maximum stress is reduced because the stress on sections between rivet holes is less than the stress on a section through the rivet holes. This ratio is still further reduced by the flange and web splices and other details. It has been assumed that these influences combined reduce the ratio of the average to the maximum stress 20 per cent.

Combining all of the influences that affect the ratio of average stress along the flange to the maximum stress on the net section at a point where the moment is a maximum, gives as the probable average stress fluctuation that affects the change in the length of the stringer span, the quantity $(18{,}000 - 1{,}220)\ 0.92 \times 0.67 \times 0.80 = 8{,}200$ lb. per sq. in. The change in length of the flange of one span is compensated for by two connections, one at each end. The deflection of the outstanding legs of the angles of one connection of a 41-ft. 1½-in. stringer is therefor

$$\frac{41.125 \times 12 \times 8{,}200}{2 \times 30{,}000{,}000} = 0.067 \text{ in.}$$

This is the amount by which the top of the outstanding leg of the connection angle will be deflected, if the distance center-to-center of floor-beam webs remains constant at mid-depth.

It remains to determine what deflection an angle can be subjected to without being overstressed and the negative moment which the connection will exert upon the end of the stringer because of the deflection. The latter is important bcause it reduces somewhat the deflection to which the angles will be subjected. Both the deflection and the moment-resisting capacity have been computed for two connections that might have been used for the stringers of the bridge being considered. One is a very stiff connection and the other a very flexible one. Angles 3/4 in. thick with a 2.25-in. gage in the outstanding leg will be used for the stiff connection and angles ⅝ in. thick with a 6-in. gage in the outstanding leg will be used for the flexible connection.

The computations show that, for the flexible connection, an outward force of 436 lb. per in. of length of angle will produce a flexural stress of 18,000 lb. per sq. in. in the outstanding leg of the angle. The connection angles are 69 in. long, with the neutral axis at mid-depth, and the two angles of a connection have a combined moment-resisting capacity of 58,000 ft.-lb. This will reduce the average stress on the gross area along the stringer flange by 420 lb. per sq. in. This reduces the deflection,

$$\frac{420}{8,200} \times 0.067 = 0.0034 \text{ in.,}$$

leaving a movement of 0.064 in. to be provided by the deflection of the angles. Apparently the moment-resisting capacity of the flexible connection does not reduce the deflection to be provided appreciably.

Computations show that an outward force of 436 lb. per in. which produces a flexural stress of 18,000 lb. per sq. in. in the angles, will deflect the outstanding leg only 0.0093 in. if the deflection is as shown in Fig. 4. This is less than one-sixth of the deflection which the computations indicate is necessary, and the elastic deflection of the angle leg corresponding to a yield-point stress is only about one-third as great as the deflection required because of the deflection of the stringer.

Consider now the stiff connection for which the angles are ¾ in. thick and have a gage of 2.25 in. Computations show that an outward force of 2,250 lb. per in. will produce a flexural stress of 18,000 lb. per sq. in. in the outstanding legs of the angle and will deflect the angle about 0.001 in. These angles have a moment-resisting capacity of 300,000 ft.-lb. and this moment at the end of a stringer will reduce the average unit flange stress along the stringer by 2,200 lb. per sq. in. This reduces the deflection to be provided for by

$$\frac{2,200}{8,200} \times 0.067 = 0.018 \text{ in.}$$

but still leaves $0.067 - 0.018 = 0.049$ in. to be provided for, whereas a deflection of 0.001 in. produces a flexural stress of 18,000 lb. per sq. in. in the angles. Apparently the moment-resisting capacity of the stiff connection is not great enough to fix the end of the stringer, and it is so stiff that it will not permit the required deflection of the angles without stressing them beyond the yield point.

The angles of the flexible connection used in the numerical problem are much more flexible than those in general use; nevertheless the computations indicate that the angles are not flexible enough to compensate for the elastic change in length of the stringer flange. On the other hand, connection angles much stiffer than the flexible ones used in the problem are known to have given satisfactory service for years and comparatively few failures of either angles or rivets have been reported. It will be of interest to consider why connection angles have functioned so successfully in service when an analysis indicates that they were stressed beyond the yield point by the loads for which the bridge is designed. It would seem that either the average stresses in the stringer flanges are less than the values used in the analysis or that the connections are more flexible than they have been assumed to be. Probably it is a combination of the two actions. They will be discussed separately in the following paragraphs.

Consider first the flange stresses. The values given are the maximum possible stresses that the specified live load will produce and they are produced only by the heaviest live load provided for in the specifications. Comparatively few trains have two of the heaviest locomotives in tandem, as has been assumed in the analysis. Since connection-angle failures are fatigue failures, the occasional overstress resulting from the few trains with two heavy locomotives is not likely to result in failure although it may represent an undesirable design condition. Moreover, the flange stress used in the computations is the average of the simultaneous stresses on two adjacent stringer spans for both of which full impact has been included. Since the impact factor for stringers has been made large to include hammer blow, flat wheels and track irregularities, the probability of simultaneous full impacts on two adjacent stringer spans is very remote.

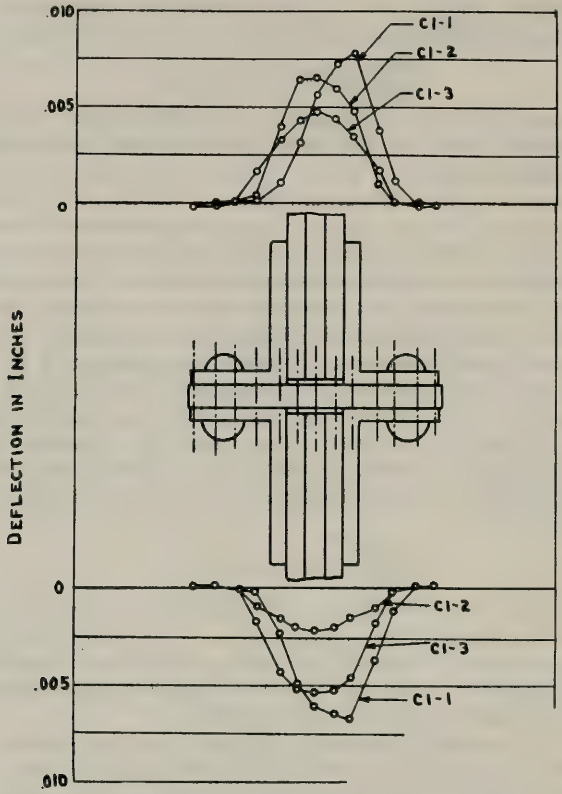

FIG. 5.—Deflection of Angles Due to Load Causing Tension in Rivets. Series C–1.

This, together with the infrequent occurrence of double-headers with heavy locomotives suggests that the stringer-flange stress used in the computations is not often realized.

Consider next the flexure of the angles. There is a belief on the part of many engineers that angles do not deflect in the manner illustrated in Fig. 4. There is a belief that the rivets elongate thereby allowing an additional movement as a direct result of the rivet elongation and a further movement due to the fact, as alleged, that the outstanding leg is not fixed at either *A* or *B* of Fig. 4. In tests already referred to,[5] the elongation of the rivet was measured as the load was applied to the connection. The largest elongation was of the order of 0.001 in. even though the external load applied to the specimen was as great as 30,000 lb. per sq. in. tension on the rivets. Moreover, the deflection diagrams of Figs. 5, 6 and 7 indicate that the rivets in the outstanding legs do clamp the toe of the angles rigidly at loads below the fatigue-strength loads for the flexible connections, but when the load exceeds the fatigue-strength load the rivets do not clamp the toe of the angles rigidly, and the deflection of the angles is considerably increased. This is indicated by both the ordinates and the slopes of the deflection diagrams of Figs. 5, 6 and 7. But is should be noted that this increased

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[5] University of Illinois Engineering Experiment Station Bulletin 317.

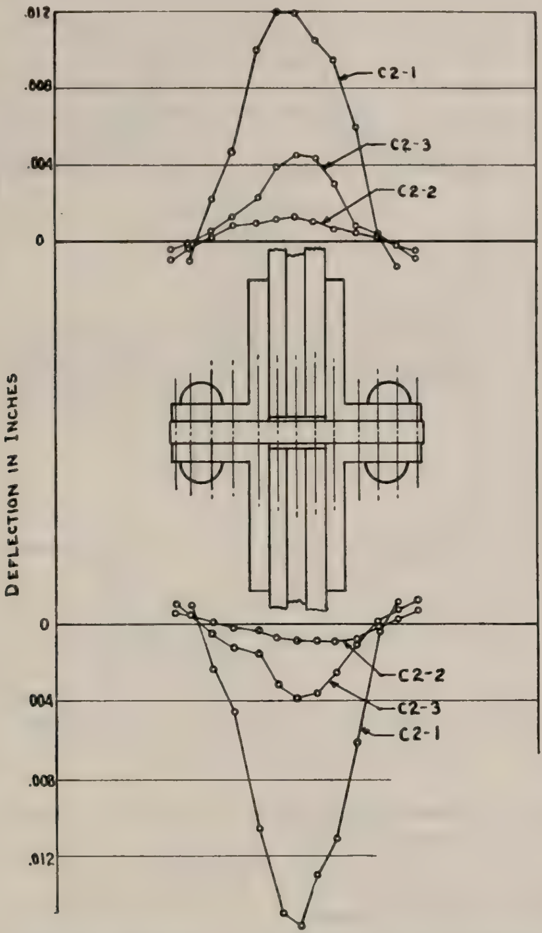

FIG. 6.—Deflection of Angles Due to Load Causing Tension in Rivets. Series C-2.

deflection is obtained only by stressing either the angles or the rivets, possibly both, beyond their yield points. Fatigue tests show that the leg of an angle in flexure can be stressed considerably beyond the yield point several thousand times without failure. It would appear, therefore, that the reason connection angles for stringers have continued in service without failure of either the angles or rivets is due in part to the fact that the stringer-flange stresses are not actually as great, except in relatively few instances, as the stresses computed under the specifications; and partly to the fact that the plastic deflection of the outstanding legs of the angles can be several times greater than the elastic deformation corresponding to a yield-point stress without producing a stress appreciably greater than the yield point.

The fact that the continued functioning of the angles can be explained on the basis that the steel can be subjected to a flexural stress somewhat greater than the yield

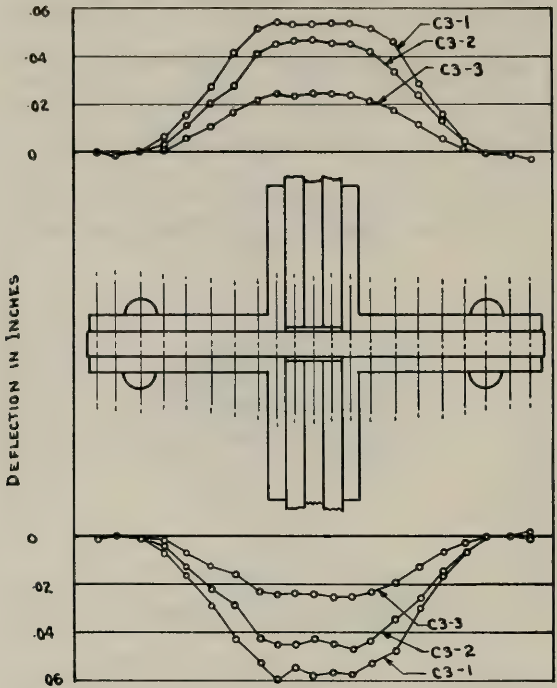

Fig. 7.—Deflection of Angles Due to Load Causing Tension in Rivets. Series C–3.

point several thousand times without failure is not to be considered as conclusive evidence that they are properly designed.

Deflection of Connection Angles Due to the Change in the Length of the Chords of the Trusses

The effect of the change in length of the chords of the trusses upon the deflection of the outstanding legs of the connection angles depends upon: (1) The average unit stress on the gross area of the chord, (2) the distance between expansion joints for the floor system, (3) the stiffness of the floor beams to resist transverse horizontal loads, and (4) the stiffness of the connection angles.

The usual design stress for chord members is 18,000 lb. per sq. in. on the net section. With a dead-load stress one-third of the total and the average stress along the chord 0.60 of the maximum on a section through the rivet holes, the fluctuations in length due to the chord stress would be

$$\frac{0.67 \times 0.60 \times 18{,}000}{30{,}000{,}000} = 0.00024 \text{ in. per in.}$$

The expansion joints in the floor of the bridge considered are spaced 164 ft. 6 in. apart, and the elongation of the chord in one-half of this length is

$$\frac{0.00024 \times 164.5 \times 12}{2} = 0.24 \text{ in.}$$

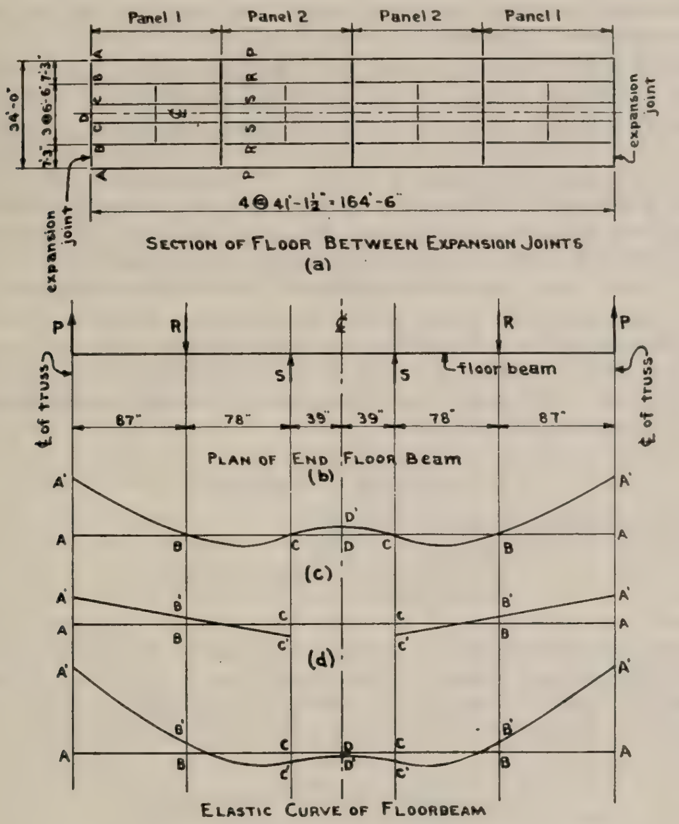

FIG. 8.—Plan of Floor Frame Included Between Adjacent Expansion Joints.

This elongation is compensated for by the horizontal deflection of the floor beam, by the deflection of the outstanding legs of the connection angles and by the axial deformation of the stringers. Computations will first be made to determine the compensating effect of the horizontal flexure of the floor beams.

A plan of that portion of the floor frame between two adjacent expansion joints is shown in Fig. 8a. The deflection of the floor beam will be determined on the basis that the ends of the stringers remain on a transverse straight line. The forces acting on the floor beam adjacent to the expansion joint are shown in Fig. 8b. The force P is the horizontal shear at the end of the floor beam where it is connected to the chord; R and S are the stringer reactions. The elastic curve will have the shape shown in Fig. 8c. From symmetry the tangent to the elastic curve at D is horizontal. This, together with the fact that B and C are on the same horizontal line, determines the relation between P, R and S. For the stringer spacing shown in Fig. 8, $R = 2.338\ P$ and $S = 1.338\ P$. With R and S expressed in terms of P, the deflection of A relative to the line $A\ B\ C$ can be expressed in terms of P. For the bridge being considered, this deflection is $0.0000141\ P$. This movement of A relative to B and C is due to the deflection of the floor beam only and is based on the assumption that *B*, *C*, *C* and *B* remain on the same straight line.

The movement of *A*, relative to the line *A B C* due to the movement of *B* and *C*, will now be determined. It depends on the section of the floor beam and stringers. Each stringer is made up of a web plate 70 in. by 3/8 in. and four flange angles 8 in. by 6 in. by ¾ in. and has a gross area of 66 sq. in. The average net section over the length of the stringer will be taken as 64 sq. in. The floor beam adjacent to the expansion joint is made up of a web plate 87 in. by 9/16 in., four flange angles 8 in. by 6 in. by 5/8 in., two cover plates 16 in. by 5/8 in. and 2 cover plates 16 in. by ½ in. The moment of inertia of the section used in computing the deflection was taken as 940 in.^4, a value slightly less than the moment of inertia of the gross section.

The axial stress in the stringer *R* is a tension equal to 2.338 *P* for the stringer in Panel 1, Fig. 8a, and 1.5 × 2.338 *P* for the stringer in Panel 2. Likewise the axial stress in the stringer *S* is a compression equal to 1.338 *P* and 1.5 × 1.338 *P* for panels 1 and 2, respectively. This being true, the axial deformation of the stringers will cause the point B, Fig. 8d, to move upward[6] an amount

$$\frac{2.338\,P\,(1+1.5)\,493.5}{64\times 30{,}000{,}000}=0.00000150\ P$$

and the point *C* to move downward[6] an amount

$$\frac{1.338\,P\,(1+1.5)\,493.5}{64\times 30{,}000{,}000}=0.00000086\ P.$$

Consider now the deflection of the outstanding legs of the connection angles due to the axial force in the stringers. The connection angles are 69 in. long. The computations in a preceding paragraph indicate that an outward force of 436 lb. per in. deflects the outstanding leg 0.0093 in. There are two angles for each connection and two connections for each of two stringer spans. The total deflection of the angles for the two panels is, therefore,

$$\frac{2.338\,P\,(1+1.5)\times 2\times 0.0093}{436\times 2\times 69}=0.00000181\ P$$

for stringer *R*, which allows the point *B* to move upward; and

$$\frac{1.338\,P\,(1+1.5)\times 2\times 0.0093}{436\times 2\times 69}=0.00000103\,P$$

for stringer *S*, which allows the point *C* to move downward.

A vertical movement of *B* relative to *C* produces a vertical movement of *A*. Letting Y_A, Y_B and Y_C represent the vertical movements of *A*, *B* and *C*, respectively, then, for the stringer spacing shown in Fig. 8,

$$Y_A=\frac{87+78}{78}(Y_B-Y_C)+Y_C.$$

For this problem Y_B is 0.00000150 *P* due to the axial deformation of the stringer and 0.00000181 *P* due to the deflection of the connection angle, or a total of 0.00000331 *P* due to both causes. Likewise, $Y_C=-[0.00000086\,P+0.00000103\,P]=-0.00000189\,P$ due to the same causes. Substituting these values of Y_B and Y_C in the equation for Y_A, gives $Y_A=0.00000911\,P$.

The calculations in a previous paragraph indicate that, due to the flexure of the floor beams, the point *A*, Fig. 8c, moves upward a distance equal to 0.0000141 *P* relative to the line *ABCCBA*. The total movement of *A* is, therefore, $0.00000911\,P + 0.0000141\,P = 0.0000232\,P$. This equals the elongation of the chord, which is 0.24 in., from which we get the equation $0.0000232\,P = 0.24$, or $P = 10{,}340$ lb. and $R = 2.338 \times 10{,}340 = 24{,}170$ lb. The outward pull on the outstanding legs of the connection angles is $\frac{24{,}170}{2 \times 69} = 175$ lb. per in. length of angle, which produces a flexural stress in the angle of 7,200 lb. per sq. in.

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[6] Upward and downward displacements in the figure represent horizontal deflections of the floor beam.

The maximum moment in the floor beam due to the horizontal forces occurs at B and equals $10{,}340 \times 87 = 900{,}000$ in.-lb. This produces a flexural stress at *B* equal to 8,600 lb. per sq. in.,[7] a stress that is usually neglected in the design of the floor beam. All of the above calculations are for the flexible connections.

If the stiff connections are used, the deflection of the floor beam and the axial deformation of the stringers will be the same, expressed in terms of *P*, as it was for the flexible connections, but the movement of *A* due to the deflection of the outstanding legs of the connection angles will be so small that it can be neglected. Considering only the deflection of the floor beam and the axial deformation of the stringer, the value of *P* to produce a movement at *A* of 0.24 in. is 13,100 lb. This horizontal force at *A* produces a flexural stress in the floor beam at *B* equal to 11,000 lb. per sq. in.

It appears, therefore, that the change in length of the chord does not produce a very large flexural stress in the connection angles of the stringers but does produce a large flexural stress in the floor beam, the value of the latter being 8,600 lb. per sq. in. if the flexible stringer connections are used and 11,000 lb. per sq. in. if the stiff ones are used.

The effect of the traction trusses has been neglected in the above discussion. The general effect of the traction truss is similar to that obtained by the use of floor beams adjacent to expansion joints which have a very high lateral stiffness. A quantitative analysis cannot be made unless the stiffness of the traction truss is known or assumed, and the only generalization that can be made is that, although a traction truss reduces the transverse flexure in the floor beams, it increases the deflection of the outstanding legs of the stringer connection angles due to the elongation of the chord.

Conclusions

The analyses presented in this report appear to justify the following conclusions:

1. The axial deformation of the chords of a through-truss railway bridge produces horizontal flexure in the floor beams with accompanying flexural stresses of the order of 8,000 to 10,000 lb. per sq. in., depending upon the stringer spacing, the floor-beam stiffness, the distance between expansion joints in the floor frame and upon the stiffness of the connection angles of the stringers. The flexural stresses in the connection angles due to the elongation of the chord are of the order of 6,000 to 7,000 lb. per sq. in. if flexible connections are used but are much smaller if the connection angles are stiff.

2. The deflection of the stringers produces a deflection of the outstanding legs of the connection angles that is several times greater than the elastic deflection corresponding to a yield-point stress. Because, for a flexural member, the elastic deformation corresponding to a specified stress varies as the square of the length, the overstress is much worse for connection angles with short stiff legs than it is for those with long flexible legs. But, even with connections more flexible than those commonly used, the deflection of the outstanding legs exceeds the elastic deflection at the yield point.

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[7] This is based on the moment of inertia of the net section.

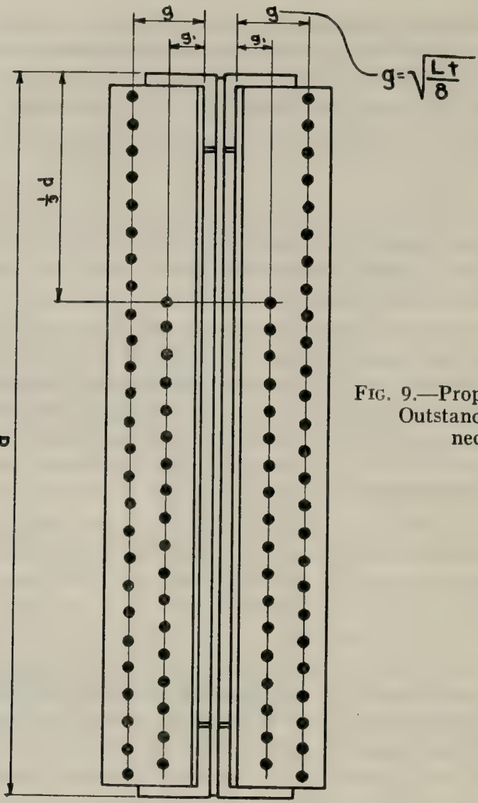

Fig. 9.—Proposed Rivet Spacing in Outstanding Legs of Connection Angles.

TABLE 1.

Design of Connection Angles for Stringers*

$$g = \sqrt{\frac{Lt}{8}}$$

Stringer Span	*Minimum Gage for the Top One-Third for the Following Angle Thicknesses, Inches*						
Feet	3/8	7/16	1/2	9/16	5/8	11/16	3/4
40............	4.74	5.11	5.47	5.80	6.12	6.42	6.70
35............	4.44	4.78	5.11	5.43	5.72	6.00	6.27
30............	4.11	4.44	4.74	5.03	5.30	5.55	5.81
25............	3.75	4.05	4.33	4.59	4.83	5.08	5.30
20............	3.34	3.62	3.87	4.11	4.33	4.54	4.74
15............	2.90	3.14	3.35	3.55	3.75	3.94	4.11
10............	2.37	2.56	2.74	2.90	3.06	3.21	3.35

* Fig. 9 shows the rivet spacing provided by the proposed rule.

3. The stresses in connection angles accompanying the deflection of the outstanding legs are deformation stresses, and, because structural steel has a well-defined yield point, a deflection ten times as great as the elastic deflection produces a stress only slightly greater than the yield point. Fatigue tests show that structural steel can be stressed beyond the yield point several thousand times without failure. The conditions of loading for maximum stress which are assumed for purposes of design are not of frequent occurrence. All of the above facts taken together are believed to account for the fact that connection angles remain in service for many years without failure of either the angles or the rivets, even though the deflection of the outstanding legs of the connection angles may be several times as great as the elastic deflection corresponding to a yield-point stress.

4. Although connection angles have remained in service many years without failure, the excessive deflection of the connection angles produces flexure in the rivets, particularly in those near the tops of the angles. Failure of these rivets is not common but they have been reported for several bridges.

5. Reasonably flexible connection angles are neither more expensive nor inferior in any way to stiff connection angles. On the other hand, they are not so likely to fail because of the deflection to which they are subjected; they are not so likely to break the rivets, and they do not produce so great a stress in the floor beams as stiff connection angles. It would seem, therefore, desirable to use connection angles that are as flexible as general considerations and engineering judgment will permit.

Recommended Practice

The connection angles for stringers transmit the shear from the stringers to the floor beams and should be designed to withstand the stresses resulting from this shear. In addition, the outstanding legs should be flexible enough so as to not be over stressed by the deflection of the stringer and the elongation of the chord. For a given flexural stress, the deflection of the outstanding leg of the angle varies directly as the thickness of the angle and inversely as the square of the gage. The design formula should, therefore, be of the form $g = \sqrt{\frac{Lt}{K}}$, in which g is the gage of the outstanding leg of the angle, L is the length of the stringer, t is the thickness of the angle and K is a constant. Because the deflection of the connection angles is small near the middle, the gage can be made smaller over the middle and bottom than over the top portion of the angles.

The following rule for design is proposed:

The gage of the outstanding legs of the connection angles over the top one-third of their length shall be not less than the quantity $\sqrt{\frac{Lt}{8}}$

The angles obtained by the use of this rule will be more flexible than angles that have been in service for many years without failure, but they will be so stiff that an analysis indicates that they are subjected to a deformation greater than the elastic deformation corresponding to the yield point every time the load for which they were designed passes over the bridge. They would seem, therefore, to represent a reasonable compromise between mathematical analysis and experience. Moreover, it is believed that the application of this design rule will not result in an abnormal connection.

Values of the gage corresponding to several values of t and L, as determined by the proposed design rule, are given in Table 1.

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Federal Valuation of Railroads

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Synopsis

This paper traces briefly the development of state and federal regulation of railroads in the United States and the early history of railroad valuation. The principal provisions of the 1913 valuation amendment, Section 19a, of the interstate commerce act are given, and the organization and personnel of the Bureau of Valuation established by the Interstate Commerce Commission to collect and compile the data underlying the physical valuation is described, with particular reference to the work of the Engineering board.

The recommendations of the Engineering board as to depreciation and other matters are stated, and the practices adopted by the Bureau are followed through the successive steps of field inventory and inspection of property, collection, assembly and pricing of the inventories, and the preparation of engineering, land and accounting reports. The tentative and final values, including going concern value and working capital, as determined by the commission, are discussed, and the principal objections to the commission's methods and findings which were made by the carriers in their protests and in the hearings on the protests are mentioned. A summary of the final values of railroad property is included.

The paper then deals with the cost of the valuation work to the government and to the railroads, the valuation work done on carriers other than steam railroads, the work of the bureau and of the commission in bringing the valuations down to date, the recapture of excess income, and the uses made of the valuations and valuation records.

Introduction

The federal valuation of the railroads of the United States of America has been completed. The act of Congress authorizing this work provides for original, or basic, valuations, the final reports of which have now all been issued, and for corrected valuations to be issued when deemed necessary by the Interstate Commerce Commission. The work was a herculean task, requiring 20 years of effort and the expenditure of a large amount of money; it might have been done in much less time had not the act required the preparation of an inventory listing the units of property in great detail as well as an investigation of the accounts and finances of the carriers. The first final value report to be issued was that of the Texas Midland Railroad, decided July 31, 1918, to which a supplemental report containing the Commission's finding of final value for rate-making purposes was issued as of July 5, 1924; the concluding basic final value report on steam railway property was issued in October, 1934, covering the property of the New York Dock Railway.

Begun in 1913

The valuation of common carriers was begun by the commission in 1913 and has continued without interruption to the present time. In all, the property of 1,826 rail transportation corporations (including such electric railways and steamship companies as were operated as parts of steam railroad systems, and The Pullman Company) was valued; this property consisted of the land, tracks, structures and equipment appurtenant to about 245,000 miles of road (about 383,000 miles of all track), and the results were made public in about 1,150 reports, a single report usually being made for all the corporations comprising a system.

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* **President AREA, 1913–1914.**

The field work, consisting of the inventory of the physical property and examination of the engineering and accounting records, was substantially completed in 1921. Since that date the valuation staff of the commission has been engaged in pricing the inventories and completing the engineering, land and accounting reports on which the commission bases its findings of values; holding hearings and conferences with carrier representatives on protested items; making reports for use in proceedings for the recapture of excess income; bringing its reports down to date, both as to changes in inventories and as to fluctuations in price levels; and, since 1935, in making valuations of common carriers by pipe line.

The valuation personnel of the commission reached a maximum of 1,573 employees in 1918, and had been reduced to 212 employees on November 1, 1937. The average for the period of field inventory was about 1,225 employees, and for the entire period 1914–1937 about 775 employees.

Total Cost $203,000,000

The expenditures for valuation to June 30, 1921, by which date most of the field work had been completed, were, by the commission, about $22,000,000, and by the railroads about $54,000,000. Since that date and to June 30, 1937, the commission expended, for valuation and related activities, the additional sum of about $28,000,000, and the railroads the additional sum of about $99,000,000, making the total approximate expenditures $50,000,000 by the commission and $153,000,000 by the railroads.

The elements of value of the property used in common carrier service by all railroad carriers, as brought down to the date January 1, 1937, by the commission's valuation staff, are: Original cost, except lands and rights, $23,019,167,496; original cost, less depreciation, except lands and rights, $16,590,227,439; cost of reproduction new, except lands and rights, $26,238,856,914; cost of reproduction less depreciation, except lands and rights, $18,906,861,318; present value of lands and rights, $2,606,869,985; working capital, including material and supplies, $300,193,743.

The sum of original cost, present value of lands and rights, and working capital as estimated by the bureau of valuation is $25,926,231,224, and the sum of cost of reproduction new, present value of lands and rights, and working capital is $29,145,920,642.

As of December 31, 1936, the capitalization of the railways, as reported to the commission, was $23,325,615,000, of which $10,346,129,000, or 44 percent, was stock, and $12,979,486,000, or 56 percent, was funded debt unmatured; the investment in road and equipment was $26,384,993,000; the balance of material and supplies account was $318,893,000; cash was $576,874,000; and accrued depreciation was $2,856,038,000. Comparison of these amounts with the estimated elements of value as of the same date indicates that for the railroads as a whole capitalization is substantially less than the cost of the assets which it represents, and investment is about equal to estimated original cost including lands and rights at their present value, but that accrued depreciation, being limited largely to depreciation on equipment, is substantially less than the depreciation of about $7,332,000,000 of the reproduction estimates, or of about $6,429,000,000 of the original cost estimates.

The approximate aggregate value of railway property used in common carrier service by all steam railroad companies was found by the commission in *Fifteen Percent Case, 1937–1938,* 226 I.C.C. 41, 62, decided March 8, 1938, to be $21,060,000,000 as of January 1, 1937. This amount does not include property or investments held for purposes other than those of a common carrier.

Development of Regulation

Initially, railroads were subject only to such governmental regulation as was provided by their charters and the rules of the common law, with an occasional statutory enactment of narrow scope. The establishment of state commissions having jurisdiction over railroads began in 1844, in New Hampshire, and by 1890, 31 states had such commissions. State regulation was concerned mainly with taxation, rates, safety, discrimination and financial abuses, and was not effective in the earlier years. It was inapplicable to interstate commerce, and many of the commissions were impowered to do little more than collect statistics.

The ineffectiveness of state regulation and the growth of abuses in the transportation industry, such as financial mismanagement, stock manipulation, extensive rebating, discrimination between shippers and between communities and territories, rate wars developing from the scramble for business, and the granting of free transportation to shippers and influential persons, led to the passage of the act to regulate commerce (the Cullom act), approved February 4, 1887. This act created the Interstate Commerce Commission, with five members, which was organized March 31, 1887 and whose authority was limited to carriers by rail or by rail and water; the act required the filing, posting and observance of tariffs, and prohibited unreasonable rates, unjust discrimination, undue preference and prejudice, pooling, and charges for short hauls in excess of those for long hauls subject to certain exceptions.

Clarifying and amplifying amendments were approved in 1889, 1891, 1895 and 1896, but the act as amended contained many defects and court interpretations weakened the act and limited the commission's powers. Additional regulatory legislation included the accident-reports act (1891), the safety-appliances act (1893), the expediting act (1903), the Elkins act (1903) putting teeth into the sections prohibitory of discriminations and deviations from published tariffs, and the immunity-of-witnesses provision (1903).

Subsequent Amendments

The Hepburn act, approved June 29, 1906, and 17 subsequent acts enacted prior to war-period legislation, effectively implemented the act to regulate commerce. The most important of the many provisions of the Hepburn act, possibly, was that which authorized the commission to prescribe rates, regulations and practices for the future. The commission was enlarged from five to seven members. The subsequent acts included among others the Mann-Elkins (Commerce Court) act (1910), the Panama Canal act (1912), the valuation act (1913), and the Esch car-service act (1917). The number of commissioners was increased to nine by the act of August 9, 1917.

To effect unity of operation necessary on account of the transportation demands incident to the World War, the President took possession and assumed control of all transportation systems, through a director general, as of January 1, 1918, by proclamation under authority of the federal possession and control act of 1916. The federal control act, approved March 21, 1918, provided for such operation.

The Transportation Act

The transportation act, 1920 (Esch-Cummins act), approved February 28, 1920, in addition to providing for the relinquishment of federal control of carriers as of February 29, 1920, and for the settlement as between the government and the carriers of matters arising from such control, had many provisions amending and amplifying the interstate commerce act. These provided for the recapture of excess income and added a rule of rate making, amplified the commission's power with respect of fixing rates and of the regulation of security issues, directed the commission to prepare and adopt a plan for the consolidation of railway properties into a limited number of systems, and required that certificates of public convenience and necessity be obtained from the commission preceding the construction, operation or abandonment of a line of railroad. The number of commissioners was increased from nine to eleven.

Later Legislation

The more important subsequent legislation affecting the regulation of railroads and the work of the commission includes the Hoch-Smith resolution (1925) providing that the Commission, in adjusting rates, shall consider the conditions prevailing in industry; the Reconstruction Finance Corporation act (1932), requiring commission approval as a condition precedent to the granting of loans to railroads by the corporation; the emergency railroad transportation act (1933), creating the office of Federal Co-ordinator of Transportation, charged with the general duty of expediting the co-ordination of services and facilities to provide a reduction in the cost of transportation, and the financial reorganization of carriers to reduce fixed charges, eliminating the provision for the recapture of excess income of Section 15a which was added by the transportation act of 1920, and substituting a new rule of rate making requiring the Commission to consider the effect of rates on the movement of traffic, the need of adequate and efficient transportation service at lowest cost, and the need of revenues to enable carriers under honest, economical and efficient management, to provide such service; the communications act (1934), creating the Federal Communications Commission and transferring to it jurisdiction over the facilities for the transmission of intelligence previously held by the Interstate Commerce Commission; the air mail act (1934), charging the commission with the duty of fixing fair and reasonable rates of compensation for the transportation of air mail, rescinded by the civil aeronautics act of 1938; and the motor carrier act (1935), extending regulation under the jurisdiction of the Commission to highway motor carriers.

The organization and activities of the Commission are described at length in *Interstate Commerce Commission Activities, 1887-1937*, prepared in the Bureau of Statistics with the co-operation of the other bureaus of the commission, and published in connection with the observance of the fiftieth anniversary of the creation of the commission.

Early History of Valuation

The concept that value should be used as a base for the determination of railroad rates was of slow development. The Illinois commission, which was the first state commission to receive mandatory rate-making power, in its 1874 report, after pointing out reasons why the cost of construction and equipment of railroads was in many cases improper as a rate base, concluded:

> * * * that the usual assumption: that the actual cost of a given road must be taken as a part of the data upon which to frame for such a road a schedule of rates, is fallacious; and that the true criterion by which to estimate its value for this purpose is the amount of business it can command. Its true value for this purpose is a sum upon which the total earnings of the road, charged at *reasonable* rates, will yield a fair return, after deducting all legitimate expenses. These earnings are necessarily limited by the amount of business there is to transact—always assuming, of course, that the road is of sufficient capacity to transact the business offered. (page 23).

The Georgia commission took a similar view, stating in its report dated November 16, 1880, pages 22 and 23:

> * * * railroad corporations are entitled to a reasonable profit on the value of their corporate property * * * .
>
> The value must be ascertained, not merely the cost, for railroad property like all others fluctuates in value, and the cost is but an element or factor in the estimate of *value.*

And in its report of May 1, 1881, at pages 37 and 40, the Georgia commission said further:

> * * * the actual cost, or money invested, is an important factor * * * .
>
> Our guide in fixing rates was set forth in our second semi-annual report in substance thus: "The rates shall yield a *fair* profit with *good average management* upon the *value* of the property, as distinguished from its costs."

The Georgia commission required the railroads, in their annual reports to the commission, to estimate the value of the properties on several bases, i. e., as the sum of the face value of debt and market value of stock, as the capitalized value of the preceding year's net income and of the average net income of the preceding five years, at the then legal rate of interest in the state, seven percent, and also to base an estimate on "all the data in possession of the company, including the past business, and any new factors, favorable or unfavorable, stating what they are."

The Mississippi commission was required, by a statute enacted in 1884, to revise the tariffs of each railroad in the state " * * * so * * * as to allow a fair and just return on the value of such railroad, its appurtenances and equipments * * * ."

The 1887 act to regulate commerce, creating the Interstate Commerce Commission, prohibited and declared unlawful "every unjust and unreasonable charge" but provided neither a measure of reasonableness nor adequate means of enforcement of rate orders of the commission. The act also authorized the commission to require annual reports from carriers, such reports to show, among other things, "the cost and value of the carrier's property, franchises, and equipment," an authorization which has remained unchanged except that by the 1906 amendment the word "equipment" was changed to the plural form. The difficulties of ascertaining cost and value, and methods of estimating value based on capitalizing net earnings and on market prices of securities are discussed in the 1888 *annual report* of the commission, wherein it is stated:

> * * * a railroad property is not necessarily worth what it would cost to replace it, and, on the other hand, it may be worth very much more than that.
>
> * * *
>
> An appraisal might perhaps be resorted to; but who can appraise the value of a franchise? What railroad official would be willing to place an estimated valuation either upon his own property or the property of his neighbor, in view of the ultimate results that might follow in respect to taxation, changes in transportation charges, or fortunes to be made or lost by dealers in securities? The difficulties surrounding this question are so great that, while the Commission has endeavored to the best of its ability to comply with the provision of the law in question, it will be found impossible to establish any safe basis of determining the result desired from any data which it has as yet been able to procure.

In its Statistics of Railways for the years 1890 and 1891 the commission reports the value of the railway property in the United States on the basis of earnings capitalized at 5 percent; in 1903 it made a valuation, in response to a Senate resolution, based on the 1900 market price of stocks and bonds; and in 1904, in co-operation with the Bureau of the Census, the commission made a commercial valuation of railway property, arrived at by capitalizing net earnings.

These methods of valuation were not satisfactory to the commission, and in its 1903 Annual Report several methods including the inventory method are discussed, and the recommendation is made that Congress take the matter of a valuation under advisement with a view to appropriate legislative action. These recommendations were renewed in each annual report from 1907 to 1912, and the usefulness of an authoritative valuation in such matters as taxation, depreciation, and capitalization as well as in the determination of a rate base was pointed out.

Valuation of Texas Railroads

The legislatures and railroad commissions of the states were interested in the valuation of railroads, both for taxation and rate purposes, the usual bases used being the capitalization of earnings or the market value of securities. The Texas Railroad Commission, created in 1891, began a valuation of the railroads in that state in 1893, and was the first to apply the inventory method, which was subsequently used in the following 20 years for valuations by state commissions in Michigan, Washington, Minnesota, Wisconsin, South Dakota, Massachusetts, Oregon, California, New Jersey, Nebraska and Kansas.

Annual conventions of representatives of the state commissions began on a national scale in 1889, when these representatives met in Washington at the invitation of the Interstate Commerce Commission to discuss matters of mutual interest. These meetings were antedated by seven conventions of regional or limted attendance beginning in 1874 with a meeting of Minnesota, Wisconsin and Illinois commissioners. These conventions resulted in the formation of the present National Association of Railroad and Utilities Commissioners. At the 1898 convention a committee was appointed to report at the next meeting on Plans for Ascertaining the Fair Valuation of Railroad Properties, and committee reports on this and related subjects appeared almost yearly from 1900 to 1913. In 1906 this association passed a resolution that Congress authorize the Interstate Commerce Commission or other federal agency to ascertain the inventory value of the railroads by states.

Influence of Judicial Decisions

Judicial decisions in railroad and public utility rate cases exerted a strong influence on valuation thought and, gave impetus to the movement for a federal valuation of the railroads. The leading railroad case was the *Nebraska Maximum Freight-Rates Case,* 169 U. S. 466, decided in 1898, commonly referred to as Smyth v. Ames, in which the Supreme Court of the United States set forth the elements to be considered in the determination of the fair value on which a property was entitled to earn a fair return. A circuit court decision in what is known as the Texas Railroad Commission case, *Metropolitan Trust Company of New York* v. *Houston and Texas Central Railroad et al,* 90 Fed. 683, also decided in 1898, declared a contested valuation by the Texas commission deficient in that no allowance was included therein for what is now often referred to as going concern value.

Support for the commission's recommendation that a federal valuation of the railroads be made was derived from the introduction in proceedings before the commission and in the courts of railroad-sponsored valuations and expert testimony which the commission found difficult to meet. A notable instance was the so-called Spokane case, *City of Spokane* v. *Northern Pacific Railway*, 15 I. C. C. 376, decided in 1909 and subsequently carried before the court. Further support to the valuation movement was given by the recommendation of the Railroad Securities (Hadley) Commission, appointed by President Taft in 1910, in its report dated November 1, 1911, that a physical valuation of the railroads by the Interstate Commerce Commission be authorized.

The Valuation Act of 1913

Valuation legislation was considered by Congress for a number of years prior to 1910, and following extensive hearings and debate Section 19a was added to the act to regulate commerce by amendment approved March 1, 1913; this section is commonly referred to as the valuation act. In general terms, the principal requirements of the act are as follows:

The commission:
- To investigate, ascertain and report the value of all property owned and used by every common carrier subject to the act to regulate commerce;
- To make an inventory listing the property in detail and showing its value, classified in accordance with the Commission's classification of expenditures for road and equipment;
- To keep itself informed of property changes and from time to time revise its valuations.

The carriers, receivers of carriers, and operating trustees:
- To co-operate with the Commission and to furnish maps and records.

The reports to show:
- For each piece of property (other than land, as amended in 1922):
  - The original cost to date;
  - The cost of reproduction new;
  - The cost of reproduction less depreciation;
  - An analysis of the methods employed;
  - The reason for the differences between the values.
- Other values and elements of value, if any:
  - An analysis of the methods employed;
  - The reason for the differences between any such value and the cost values.
- For lands, separately from improvements:
  - The original cost as of the time of dedication to public use;
  - The present value;
  - The original and present cost of condemnation and damages, or of purchase in excess of original cost or present value (omitted by 1922 act).
- For non-carrier property:
  - The original cost;
  - The present value;
  - An analysis of the methods employed.
- The history and organization of the present and previous corporations.
- The security issues, financing arrangements, earnings and expenditures.
- The amount and value of aids, gifts, grants and donations.
- The value of the property of every common carrier as a whole, and separately in each state, territory and the District of Columbia, classified and in detail as provided by the act.

Under the procedure specified in the act, carriers and other interested parties have 30 days in which to protest tentative valuations and if no protests are filed the tentative valuations become final. If protests are filed, the commission is directed to hold hearings, make such changes in its valuations as may be necessary, and the corrected tentative valuations then become final.

Final valuations are, by the act, prima facie evidence of the value of the property in all proceedings under the act and in judicial proceedings to enjoin, set aside, annul, or suspend any order of the commission.

Also by the act, in a trial of any action involving a final value, if any evidence is introduced which is different from or additional to that offered upon the hearing before the commission, the court shall stay proceedings and transmit such evidence to the commission and the commission may amend its final value order, such amended order to take the place of the original order. United States district courts are given jurisdiction to issue writs of mandamus commanding carriers to comply with the provisions of Section 19a.

Amendments and acts supplemental to the valuation act have been few. In 1914 legislation relative to the transportation of valuation field parties was approved. In 1922 the costs of reproduction required to be reported were limited to property other than land, and the requirement that the original and present cost of condemnation and damages with respect of land, or of purchase in excess of original cost or present value, was stricken. In 1933 the emergency railroad transportation act added an exception as to the applicability of the act to electric railways, and also relieved the commission of the requirement of ascertaining "in like manner" the values of property changes made subsequent to the original valuations. In 1934 the communications act relieved the Interstate Commerce Commission of its jurisdiction over the facilities for the transmission of intelligence; subsequently the commission completed its valuation of certain telegraph company property at the request of the Federal Communications Commission.

The Bureau of Valuation

Neither the extent of the work imposed by the detailed requirements of the valuation act nor the time which would be required to complete it was at first realized. The property to be valued was owned by some 1,900 corporations and comprised about 383,000 miles of track of which about 245,000 miles were first main track, 63,000 locoomtives, 52,000 passenger-train cars, 2,400,000 freight and other cars, with all of the buildings, structures, machinery and other apparatus, and the right-of-way and other lands forming the transportation structure of the country. Detailed inventories of this property, priced and depreciated, were required, with the present values of the lands and historical and accounting data regarding each corporation and its predecessors.

The act provided that the work should be begun within 60 days of its approval, and the commission without delay organized a division of valuation which was expanded as the work progressed and as experience dictated. The division was renamed the Bureau of Valuation in October, 1917. The bureau, with a Director of Valuation at its head, consisted of an engineering section under the direction of an Engineering Board, a land section under a supervisor of land appraisals, and an accounting section under a supervisor of accounts. The commission also named an advisory board of five members to review the plans made for the prosecution of the valuation work.

Division 1

In 1917, by amendment of the interstate commerce act, the commission was permitted to divide its membership into divisions, each division being authorized to decide the issues presented to it, subject to appeal to the commisson as a whole. The subject of valuation was assigned to Division 1. All valuation cases decided prior to

July 6, 1924, and 12 cases decided subsequent to that date, are reported as "By the Commission" and other cases "By Division 1."

Director of Valuation

The Commission named Charles A. Prouty to take active charge of the valuation work. Judge Prouty, who had been a member of the commission since 1896, resigned from the commission and was appointed director of valuation as of February 3, 1914, serving as such until his death on July 8, 1921. His successor as director was Charles F. Staples, who had been a member of the advisory board since 1913. Following the death of Mr. Staples on June 24, 1932, Ernest I. Lewis, who had been a member of the commission since 1921, was appointed director of valuation as of January 1, 1933, immediately following the expiration of his term as commissioner.

Engineering Board

The organization and direction of the engineering section was placed in the hands of a board of five engineers, the function of the board being stated in a press release by the commission dated April 26, 1913, as follows:

> The first important step in the direction of organization of forces with which to carry on this [valuation] work, will be the selection of a board of engineers who will assist the commission in formulating the plans under which the work will be done, and who will have direct charge of carrying out those plans in different portions of the country. * * *
>
> This board will meet in Washington on or shortly after May 1, and proceed immediately in co-operation and conference with the commission, to outline plans for the engineering features of the work.

The appointees to the engineering board were William D. Pence of Wisconsin, Robert A. Thompson of California, Howard M. Jones of Tennessee, John S. Worley of Missouri, and Edwin F. Wendt of Pennsylvania, all of whom had been in railway engineering service, and two of whom had been chief engineers of state railroad commissions while those commissions were engaged in making railroad valuations. Mr. Carl C. Witt of Kansas succeeded Mr. Worley on the Board on January 1, 1920.

Informal meetings of the board began at Washington on May 1, 1913, and formal meetings on May 6, continuing, with occasional adjournments, until June 17, 1914. Thereafter the board convened from time to time for series of meetings, usually at Washington, D. C., but twice at Chicago and once at Portland, Me. The last meeting was held on September 22, 1920 and the total number of formal meetings was 283. Chairmanship of the meetings was rotated among the members; minutes of the meetings were kept; communications between the board and the director were in the form of memoranda, these memoranda and the minutes of the meetings forming a permanent record of the progress of the work and of the decisions which were made. Up to the date of dissolution of the board in 1921 the director sent 841 formal, numbered memoranda to the board, and the board sent 368 to the director.

The preliminary work of the board was concerned with organization, interpretation of the requirements of the act, personnel, and the principles and methods under which the work was to be prosecuted. In a memorandum to the director dated May 24, 1913, the board stated:

> (a) The organization of the board, its internal workings, and the organization of the working forces should be such, that the disability or retirement of one or more members of the board or of a number of the working forces, would not

impair the work, and at the end of any period, all that had been done at a prior date could be substantiated by those remaining. In other words, no part of the work should be dependent upon a single individual, and the work would at all times be insured to the government.

(b) The work is of such vital importance, it is imperative that its integrity be beyond question. Such being the case, no expense should be spared in adopting the best methods. However, after the best methods have been adopted, the work should be executed in the most economical and efficient manner.

Organization

In order that the supervisory and office forces of the bureau might not be too remote from the scene of field operations, five district offices were established, each district being assigned about 50,000 miles of road to inventory with a part of such mileage in southern territory in which field work could be performed in the winter months. Each district was under the general supervision of a member of the engineering board, the Eastern district, with headquarters in Washington, D. C., under Mr. Wendt; the Central district, with headquarters in Chicago, under Mr. Pence; the Western district, with headquarters in Kansas City, Mo., under Mr. Worley; the Southern district, with headquarters in Chattanooga, Tenn., under Mr. Jones; and the Pacific district, with headquarters in San Francisco, Cal., under Mr. Thompson. Assisting the members of the board in each district were a district engineer and an assistant district engineer who had charge of the office work.

As personnel was added the district engineering staffs were organized into branches in charge of senior engineers, a roadway branch, a building branch, a bridge branch, a mechanical and electrical branch, a signal branch, and a telegraph and telephone branch. A valuation attorney in each district was in charge of the land section, and a district accountant of the accounting section.

With the practical completion of the field work in 1921 the commission decided to discontinue the five district offices and concentrate the work of pricing and preparing reports in Washington; this was done as of October 31, 1921, the engineering board being dissolved and the engineering section reorganized under a supervising engineer. Such members of the personnel of the district offices as were needed and who so desired were transferred to Washington.

Personnel

Employees below the grade of district engineer were selected through competitive examinations conducted by the Civil Service Commission, with which the engineering board co-operated in establishing specifications for the positions to be filled and the salary ranges for the various grades, and in grading the examination papers. The first examinations for engineers, inspectors, architects and examiners of accounts were held in July, 1913; there were 7,278 applications for positions on the engineering force and 2,395 applications for examiners of accounts, exclusive of telegraph and telephone engineers and land appraisers, examinations for which were given at a later date. Rosters of eligibles were prepared both by districts and for the entire United States, but it was the general practice in making appointments to fill positions in a district from the roster for that district.

The number of employees of the bureau including field men, district office and Washington general office employees increased rapidly from slightly more than 400 in the fiscal year 1914 to a maximum of 1,573 in the fiscal year 1918. In 1920 and 1921 about 1,000 persons were employed, but this number was reduced by about one-half when the district offices were discontinued in 1921. The number remained at about 500 employees through the fiscal year 1927, followed by an increase in number to 975 employees in 1931. The repeal of the recapture provisions of Section 15a of the transportation act in 1933, and retrenchment due to prevailing economic conditions were reflected in a substantial reduction in personnel, the number of employees dropping from 910 on June 1, 1933 to 381 active employees on July 1, 1933, and further reductions have been made in subsequent years following completion of the basic valuations and the placing on a current basis of the work of bringing the valuations down to date. The number of employees of the bureau has been reported as shown in Table 1 for the fiscal years beginning with 1913 and on certain dates as shown.

TABLE 1

NUMBER OF EMPLOYEES OF BUREAU OF VALUATION

Year Ended June 30	*Number of Employees*	*Year Ended June 30*	*Number of Employees*
1913	13	1928	667
1914	429	1929	641
1915	1,261	1930	708
1916	1,480	1931	975
1917	1,562	1932	942
1918	1,573	Date	
1919	1,530	June 1, 1933	910
1920	990	July 1, 1933	381
1921	996	Dec. 1, 1933	363
1922	585		
1923	543	1935 (a)	353
1924	415	Nov. 1, 1935	301
1925	439	Nov. 1, 1936	243
1926	542	Nov. 1, 1937	212
1927	535		

Note (a). Number of employees reduced from 353 to 304 during fiscal year 1935.

In 1917 the staff of the Bureau of Valuation was near its peak in point of numbers and these employees comprised about 70 percent of the entire staff of the commission; the ratio was about 30 percent in 1925, about 40 percent in 1931 and 1932, about 25 percent in 1933, and about 11 percent on December 31, 1936.

Salaries and Expense Allowances

The commission was obliged to increase the salaries of the employees of the bureau from time to time in order to compensate for the substantial increases in the cost of living after 1914, and to retain the services of the technical experts who, because of their experience in valuation work, could be replaced with difficulty. The administrative and technical staff of the Washington general office in 1921 consisted of a director at $10,000 per year, a member of the advisory board at $9,000, a resident engineer at $6,000, three valuation analysts at from $3,000 to $4,200, a supervisor of land appraisals at $9,000, an assistant supervisor of land appraisals at $6,000, five senior land appraisers at from $2,100 to $3,000, a supervisor of accounts at $9,000, two assistant supervisors of accounts at $5,000 and $4,200 respectively, a solicitor at $7,500, six attorneys and examiners at from $3,000 to $5,000, and four senior civil engineers at from $2,100 to $3,600.

Each of the five district offices had about 100 administrative and technical employees in 1921, when the field work was practically completed. An average staff at this time consisted of a member of the engineering board at $9,000 per year, a district engineer at $6,000, an assistant district engineer at $5,000, and 5 senior engineers at $3,900 or $4,500 in charge of the bridge, building, mechanical and electrical, signal, and telegraph and telephone branches. The salary range of the senior and junior grade engineers and inspectors was from $1,320 to $3,600 per year, and there were on the average in each district 29 civil engineers, 6 structural engineers, 3 architects, 8 mechanical and electrical engineers and inspectors of equipment, and 5 signal and telegraph and telephone engineers and inspectors. The salary range of rodmen and chainmen of the roadway field parties was from $720 to $1,200 per year. In the land section were a valuation attorney in charge at $6,000, and 10 land appraisers of junior and senior grades at from $1,380 to $3,600, and in the accounting section a district accountant in charge at $6,000, an assistant district accountant at $4,200, and 26 accountants at from $2,100 to $3,900.

The per diem allowances for subsistence of the men in roadway field parties while living in outfit cars were first set at $1.50 for the chiefs of party and $1 for others; these amounts were increased to $1.75 and $1.25, respectively, on December 1, 1917. The per diem allowances for other field employees varied from $2.50 to $5 during the first few years of the field work, and were established at $4 for all such employees on February 1, 1918.

Co-operation

The carriers individually and through their committees co-operated actively with the bureau both in the preliminary stages of the work and throughout the period of inventory and preparation of reports. The principal medium of co-operation by the railroads jointly was a committee of representatives of the railroads which later became the Presidents' Conference Committee on Federal Valuation of the Railroads in the United States, PCC for short, which was formed in 1913 and established offices in Philadelphia, Pa., under a permanent secretary and branch offices in New York and Chicago. The engineering board held two-day conferences with this committee in June, July, September and October of 1913, a one-day conference in December, and conferences of one or two days each in February and June of 1914 and in January and May of 1915. The board and the bureau also maintained informal contact with the committee throughout the valuation work by correspondence and conferences.

Prior to service on the carriers by the commission of its Valuation Order No. 1, containing specifications for maps and profiles to be furnished by carriers, on January 12, 1914, tentative specifications drawn up by the engineering board were submitted to the carriers and others concerned for criticism and the subject was taken up at joint conferences between the board and the PCC. The advice of the carriers was similarly sought in the drafting of the more important subsequent valuation orders.

Individual carriers co-operated with the bureau, beyond the requirements of the strict letter of the law, by furnishing maps, records and cost data, by appointing representatives to accompany the bureau's field parties, by assisting in the computation of quantities from the field notes, and by constructive criticism. The valuation departments of the carriers were, as a rule, ably staffed, and were of great assistance to the bureau in the work of compiling a complete and accurate inventory of carrier property.

In addition to the conferences with the Presidents' Conference Committee the engineering board also held conferences with representatives of the telephone and telegraph companies, in September, October and December of 1913, in February and June of 1914, and in June, 1915, at which arrangements for the inventory of the property of those companies were made.

The valuation committee of the National Association of Railway and Utilities Commissioners met in conference with the board in July, 1913, and attended, by invitation of the commission, the conferences between the board and the Presidents' Conference Committee. In some instances state commissions intervened in valuation hearings on carriers having properties within their respective states and presented testimony having to do with the valuation of those properties.

Depreciation

The subject of depreciation did not receive formal action by the engineering board in the first year of the board's work while the problems of organization and of the initiation of field work were paramount. The first tentative drafts of instructions to road and track, bridge, and building field parties, prepared in the first six months of 1914, contained only a brief section, phrased in general terms, respecting the notes to be made of the condition of property inspected, but all subsequent issues of such instructions to all parties contained an amplified section on condition. The data called for by these instructions were, in brief, (a) age, and if second-hand, length and nature of service elsewhere; (b) wear and decay, record of such facts as were practicable from field observation; (c) maintenance, normal or above or below normal, extensive or unusual repairs needed; and (d) probable service life, local conditions affecting life, evidence as to inadequacy or obsolescence, field evidence as to probable remaining service life.

Memorandum 226

Upon request of the director made in May, 1914, the board gave long and careful consideration to the question of the depreciation of carrier property and submitted to the director its Memorandum 226 on this subject dated June 7, 1915. This memorandum was revised as of October 30, 1915 and again as of November 6, 1915 and was slightly modified by the director under date of November 15, 1915. Memorandum 226 has been the guide used by the bureau in estimating the depreciation of property in all of its valuations, and was included in its entirety by the commission in its report and order on the *Texas Midland Railroad*, Valuation Docket 2, 75 I. C. C. 1, 183.

The board defined depreciation in Memorandum 226 as "the lessening in worth of physical property due to use or other causes." This definition, while more general, agrees in substance with that laid down by Chief Justice Hughes, speaking for the Supreme Court of the United States, as recently as April 30, 1934 in the so-called Chicago telephone case, *Lindheimer* v. *Illinois Bell Telephone Co.*, 292 U. S. 167, wherein he said:

> Broadly speaking, depreciation is the loss, not restored by current maintenance, which is due to all the factors causing the ultimate retirement of the property. These factors embrace wear and tear, decay, inadequacy, and obsolescence.

Following the definitions of depreciation and of its elements, Memorandum 226 contained general rules to be applied in estimating the condition of property and specific rules for the property in each road and equipment account. Under these rules depreciation was determined on the straight-line basis as the ratio of expired service life to estimated total service life, scrap and salvage values being given consideration. No depreciation was applied to engineering, excavation, or embankment. The estimated normal service lives prescribed for concrete and masonry were 100 years; for metal bridges, 70 years; for cast-iron culvert pipe, 80 years; for other iron or steel culvert pipe, 30 years; for vitrified and concrete culvert pipe, 50 years; for new rail laid in side tracks, 75 years; for the second cycle of rail (relay to scrap), 50 years; for timber buildings, 50 years; for telegraph and telephone wire, iron, 50 years and copper, 100 years. Rails and splices were depreciated in two life cycles, new to relay, and relay to scrap, spikes were depreciated with the ties with which they were used, and all other items of other track material were depreciated from new to scrap with each rail cycle. Track laying and surfacing was depreciated as the weighted average of ties, rails, other track material and ballast; and ties, rails, frogs, and switches were given depreciation of 50 percent when yearly renewals had become uniform. For those classes of property for which no service lives were fixed by the board, and for property considered not in normal condition for its age, the field engineers exercised their judgment.

Memorandum 226 omits reference to depreciation of the general expenditures accounts. In a memorandum to the board dated December 14, 1916, the director set forth the rule that general expenditures and interest during construction should be depreciated in proportion to the depreciation of the accounts of which general expenditures and interest were computed as percentages.

Obsolescence

Obsolescence as an element of depreciation is not specifically mentioned in Memorandum 226, but in the instructions to field parties inspectors are directed to: "Record any evidence which may be ascertained in the field as to the inadequacy or obsolescence of the property." In the statement of methods included as Appendix 3 in the valuation report on *Texas Midland Railroad*, 75 I. C. C. 1, 108, the commission states: "Functional depreciation results from the want of adaptation to function. * * * As to the present, the engineers are instructed to consider functional depreciation which has already occurred. * * * As for the future, the instruction is that functional depreciation shall only be considered when it is imminent." The extent to which obsolescence enters into the depreciation as found, averaging in excess of 20 percent for all steam railway property, is, therefore, conjectural.

The definition of depreciation and the rules for its determination adopted by the board were based on the general instructions of the commission relating to depreciation contained in various classifications of accounts. Up to 1907 the classifications of operating expenses prescribed by the commission for steam railroads contained no accounts to which depreciation was to be charged, and renewals of property retired were chargeable to the operating expense accounts, but in the classification made effective July 1, 1907, depreciation accounts "to provide a fund for replacement when retired" were included for each class of equipment but not for fixed property. The text of these accounts was amplified in the supplement to this classification made effective July 1, 1908, and similar accounts for the charging of depreciation on vessels and rolling stock were contained in the classification relating to "outside operations" (ferry lines, sleeping car service, etc.) of steam railroads also effective July 1, 1908, and for vessels, tugs and lighters in the classification for carriers by water made effective January 1, 1911. The classification of operating expenses of steam railroads which was made effective July 1, 1914, contained depreciation accounts for fixed improvements the use of which by the carriers was optional, and depreciation accounts for equipment the use of which was mandatory; the instructions provided that:

> * * * Such depreciation charges shall be based in each instance upon the percentage of original cost (estimated if not known), ledger value, or purchase price of the property determined to be equitable by the carrier's experience and best sources of information as to the actual current loss from depreciation. A statement of the bases used by the carrier for computing these charges shall be included in its annual report to the commission.

The classifications for telephone companies effective January 1, 1913, and for telegraph and cable companies effective January 1, 1914, also contained depreciation accounts; the instructions relative to these accounts were substantially the same in the two classifications, those for telegraph and cable companies reading as follows:

> Sec. 21. Depreciation of plant and equipment.—Telegraph and cable companies should include in operating expenses depreciation charges for the purpose of creating proper and adequate reserves to cover the expenses of depreciation currently accruing in the tangible plant and equipment. By *expense of depreciation* is meant—
>
> (a) Losses suffered through the current lessening in value of tangible property from wear and tear not covered by current repairs;
>
> (b) Obsolescence or inadequacy resulting from age, physical change, or supersession by reason of new inventions and discoveries, changes in popular demand, or public requirements;
>
> (c) Losses suffered through destruction of property by extraordinary casualties.
>
> The rate of depreciation should be fixed so as to distribute, as nearly as may be, evenly throughout the life of the depreciating property the burden of extraordinary repairs and the cost of capital consumed in operations during a given month or year, and should be based upon the average life of the units comprised in any class of property.

The board's recommendation of June 9, 1915, that consideration be given to the depreciation which accrues during the construction period when determining the cost of reproduction new of such items as timber bridges and culverts, ties, rails and fastenings was neither approved nor disapproved by the director, but he directed that no account be taken of such form of depreciation.

Subject of Disagreement

During the entire progress of the valuation work, from the field inventory stage to the period of hearings and arguments, depreciation was a subject concerning which there was continued disagreement between the carriers on the one hand, and the bureau and the commission on the other. Many carriers were reluctant to permit their representatives to place their signatures on field notes on which the condition or estimated probable service life of the property had been noted, or to join with the engineers of the commission in making such condition estimates. In the hearings on protested tentative valuations, the carriers generally asserted the principle that in the absence of deferred maintenance there is no depreciation of railway property. The following quotation from the valuation report on *The Pennsylvania Railroad Company et al* is typical, and illustrates the opposing viewpoints:

> * * * The carriers protest against the principles, methods, and rules employed in the determination of cost of reproduction less depreciation and against the results of their application. They maintain that the amounts ascertained and deducted as depreciation are but speculative estimates of future operating costs and are not depreciation. They further maintain that the service life of their properties is continuous and indefinite and that there is never at any time any known or ascertainable part of this service life which has expired. In other words, they contend that depreciation does not exist in well-maintained railroad properties.
>
> * * *
>
> Wherever in conference there was an agreement on cost of reproduction new, there was also an agreement on the correctness, under our principles, methods and rules, of the corresponding estimate of cost of reproduction less depreciation, the

> carriers at the same time reserving their objections to the application of the principle of cost of reproduction less depreciation and to the rules and methods which we have established.
>
> Contentions similar to those here advanced have been considered and rejected in previously decided cases.
>
> * * * the protests are denied. (22 I. C. C. Val. Rep. 1, 115, 116)

In percentage, the average depreciation on all physical property, except land, owned and used in transportation service by the 1,704 steam railways for which valuation reports at 1914 normal prices were issued, as reported by the Commission, was 20.5 percent. From exhibits prepared by the bureau and introduced in *General Rate Level Investigation, 1933,* Docket 26000, and in *Fifteen Percent Case, 1937-1938,* Ex Parte 123, the estimated depreciation is found to be 25.9 percent as of January 1, 1933, and 27.9 percent as of January 1, 1937. A comparison by territorial districts is as follows:

	Depreciation (Percents)			
District	*Eastern*	*Southern*	*Western*	*Total*
Original valuations	21.4	19.8	19.8	20.5
January 1, 1933	25.7	24.5	26.6	25.9
January 1, 1937	28.8	28.0	27.0	27.9
Increase	7.4	8.2	7.2	7.4

The weighted average date of valuation of the 1,704 railways is estimated as being in the year 1917, so that the average yearly increase in the total depreciation, as estimated by the bureau, in the 19-year period from the end of that year to January 1, 1937, was about 0.4 percent, without allowance for the effect of the expenditures by the carriers for new lines and extensions and additions and betterments amounting to in excess of 10 billion dollars in the period.

If the effect of additions and retirements of property is given consideration, it is found that the average rate of depreciation is in excess of one percent per year. At this rate of depreciation, there will be a decrease in the average percent of cost new of all the carriers in each year in which the expenditures for property additions and betterments do not exceed about one billion dollars, assuming normal maintenance, an amount expended in only one year, 1923, and about 25 percent in excess of the average expenditure in the post-war, pre-depression period from 1920 to 1930 inclusive.

The Engineering Section

The inventory, pricing and depreciation of all of the physical property, except land, used in transportation service by the carriers under valuation was the responsibility of the engineering section; land and non-carrier property were inventoried and appraised by the land section. Organization of the engineering section into branches staffed with specialists provided flexibility and close control of the work, and while there was some overlapping between branches this presented no serious difficulties. In general, roadbed and track were inventoried by the roadway branch, bridges and similar structures by the bridge branch, buildings and structures by the building branch, telegraph and telephone lines by the telegraph and telephone branch, signals by the signal branch, and machinery, power transmission and distribution systems, roadway machines, locomotives, cars and other equipment by the mechanical and electrical branch.

Dates of Valuation

It was at first assumed that the properties of all carriers would be valued as of the same date, but very early in the work it became evident that this would be impracticable due to the length of time that would necessarily elapse between the beginning and completion of the field inventory and the constant changes in the properties, and each carrier was then assigned a date of valuation, which became the date as of which the inventory of the property was prepared, by the member of the engineering board in charge of the district to which the carrier had been assigned for inventory. The date assigned was usually June 30 of the year in which the field work was scheduled to be performed. The valuation dates of the 1,704 railway properties on which final values based on 1914 normal prices were issued, were grouped as follows:

Valuation Date	*Number of Properties*
June 30, 1914	66
June 30, 1915	153
June 30, 1916	412
June 30, 1917	416
June 30, 1918	476
June 30, 1919	171
June 30, 1920	3
Dec. 31, 1920	4
June 30, 1921	1
Dec. 31, 1921	1
Dec. 31, 1922	1
Total	1,704

Subsequent to the original valuations, reports were issued on 121 other railway carriers which had come into existence after the original valuations were made, or which had not been included in the original schedule for various reasons. The date of valuation assigned to 95 of these properties was December 31, 1927, and that assigned to the remaining 26 properties was December 31, 1928.

Valuation Sections

For convenience in prosecuting the field work, in assembling quantities, and in filing maps and records, each carrier property was divided into valuation sections and subsections, such division ordinarily being made by the carrier with the approval of the district office of the bureau to which the carrier was assigned for inventory. Valuation sections were arranged to distinguish property within a state and corporate ownership, and when desirable, important branch lines, major terminals, division points, and valuation sections as established by state commissions; subsections to distinguish short discontinuous portions of main line, jointly owned or used property, important branch lines and important spurs, and minor terminals.

Inventory quantities were assembled by valuation sections, and several valuation sections combined to form a collection section, but unit prices were not necessarily established by valuation sections.

Field Inventory

It was the desire of the commission that field work be initiated without delay, but the complexities of the work of organization, the opening of district offices, and the necessity of recruiting personnel through civil service procedure made it impracticable to begin the field inventory before about February 1, 1914, when two roadway field parties in each district began work. The engineering board prepared a set of pamphlets containing instructions for the field work of the roadway, bridge, building, telegraph and telephone, signal and mechanical and electrical branches which were followed throughout the work and assisted in establishing uniformity of methods in the several districts. These instructions embodied many suggestions made by representatives of the carriers and state commissions, with whom the tentative instructions were discussed before being issued in corrected and final form. The instructions contain general information as to the duties of the personnel and specific instructions as to the accounts and property to be inventoried, the descriptive data to be recorded as to each unit, and the information required to estimate the depreciation of the property inventoried.

The first roads to be inventoried were selected with some care, the selection being based upon the adequacy of the maps and records available for the use of the bureau, and upon the variety of the problems which these first inventories would present. The first field work in the Eastern district was on the Norfolk Southern, in the Southern district on the Atlanta, Birmingham & Atlantic, in the Central district on the New Orleans, Texas & Mexico, in the Western district on the Texas Midland, and in the Pacific district on the San Pedro, Los Angeles & Salt Lake.

The number of roadway field parties was increased to eight in each district by September, 1914, and to twelve in each district by June, 1915, this force being maintained until the roadway field inventory was nearing completion. A regular field party of nine men included one assistant field engineer in charge of the party, one recorder, two computers, one instrument man, one rodman, one head chainman, one rear chainman and one tapeman. A clerk was added in some instances, and a cook and a laborer were attached to parties which subsisted in outfit cars. Special terminal parties were organized for the inventory of a number of the larger terminal properties.

The roadway parties working on the inventory of a particular carrier were under the immediate direction of a field engineer whose duties were to co-ordinate the work of the parties and see that they were disposed to the best advantage, to confer with the officers of the carrier under inventory, and to obtain from the records of the carrier such data and information as were pertinent to the valuation.

A representative of the carrier under inventory was attached to each field party. Usually this representative, or "pilot," was an engineer familiar with the railroad, who could make known the carrier's claims as to the use and ownership of property, and hidden quantities.

From the cross-section and chaining notes the field parties partially computed and summarized the quantities in the roadway accounts, including grading and protection of roadway property, tunnels, ties, rails, other track material, ballast, track laying and surfacing, fencing, crossings, signs and paving. The location of fixed improvements such as bridges and buildings was also shown on the chaining notes.

When the field inventory was first begun the roadway parties subsisted in boarding houses or hotels, but this was found to be entirely unsatisfactory in most instances, and early in 1914 arrangements were made for the purchase of outfit cars, converted from sleeping cars, for the subsistence of the roadway parties. These cars were equipped with bunks for the members of the party, shower bath, office space and kitchen. When in the field, the cars were parked on sidings in the vicinity of the work and moved from time to time as the work progressed.

Consist of Field Parties

Field parties of the branches other than roadway usually consisted of one man who was accompanied by a representative of the carrier, or "pilot," to point out the property, assist in the inventory, and furnish from the carrier's records the ages of structures and other data. All fixed property was inspected and inventoried in detail. The carriers often provided, as pre-inventory data, lists of roadway and shop small tools and of the furniture and fixtures in buildings, and in some instances prepared the field notes in certain accounts in advance, for check by the bureau's field parties.

Field notes were made in duplicate by the use of carbon paper on a series of printed forms 11 in. by 8½ in. in size adapted for the various classes of property, and were signed by both the party chief and carrier's representative and the carbon copies turned over to the carrier. Collection sheets for the summarization of inventory quantities were also prepared in duplicate on printed forms, usually 17 in. by 11 in. in size, and copies of certain of these forms were supplied to the carrier.

Most of the carriers under valuation entered into co-operative agreements with the bureau which provided for delivery of carbon copies of field notes to the carriers, that carriers should call attention to alleged erorrs or omissions in the notes within 30 days, and that carrier's claims on account of property not open to visual observation and measurement should be definitely indicated before or at the time of the field survey; the agreement also provided for the correction of errors in field notes and for the settlement of questions of differences. This agreement was drawn up by the director after discussion with and recommendation by the engineering board; the first form of the agreement is contained in Valuation Circular No. 1, *Preliminary Work by Carriers*, issued by the director under date of May 1, 1914. The time for filing objections to the field notes was extended to 60 days in 1915.

The act prescribes that the commission, in its valuations, "shall classify the physical property, as nearly as practicable, in conformity with the classification of expenditures for road and equipment, as prescribed by the Interstate Commerce Commission." The title of the classification as revised effective July 1, 1914, was changed to classification of investment in road and equipment, and prior to its revision effective January 1, 1936, it comprised 62 accounts, of which numbers 1 to 47 include the road, or fixed, property, numbers 51 to 58 equipment, and numbers 71 to 77 general expenditures.

Account 1, Engineering

In the final valuations of steam railway properties issued by the commission, engineering in the cost of reproduction estimates was computed as a percentage of the cost of reproduction new of the road accounts exclusive of land and assessments for public improvements, and was not depreciated. Four percent was used more often than any other rate, the range being from 2¼ percent to 5 percent and the weighted average rate was about 4.03 percent. More than one rate was frequently used in the case of a single railroad, a higher rate being taken for an important terminal, for example, than for the balance of the property. No additional allowance was made for engineering costs in connection with equipment, it being assumed that such costs were included in the unit prices allowed for the equipment itself. The percentages adopted are intended to exclude the cost of preliminary (reconnaissance) engineering work in connection with the location of line, under the theory that such costs would not be incurred in reproducing a railroad the location of which is known. This theory, and the rates recommended by the bureau in the tentative valuations, were contested by many carriers in the hearings on their tentative valuations.

The method and the range of rates used by the bureau conformed to recommendations of the engineering board which had the approval of the director, and which were approved by the commission in its first valuation decision, that of the *Texas Midland Railroad*, on July 31, 1918. Support for the rates adopted was based on a study made by the field accountants of the bureau of the overhead costs, including engineering, general expenditures except interest, and interest during construction, incurred on 121 railroad construction projects in different sections of the country built over a long period of years prior to 1914. A summary of this study was introduced in evidence by the bureau in a number of valuation cases and was commonly referred to as the Brown exhibit.

Account 2, Land for Transportation Purposes

The discussion of Account 2, Land for Transportation Purposes will be found in the chapter headed The Land Section.

Account 3, Grading

Grading cross-sections were taken normally at 100-ft. stations, and pay quantities computed and priced in accordance with the director's instructions of April, 1916, which substantially followed the recommendations of the engineering board, and under which the one-way method, with pay quantities expressed and priced in terms of excavation, was mandatory when the quantity in cut exceeded one-third of the total quantity of cut and embankment and the two-way method, with pay quantities of excavation and embankment separately priced, was permissive in all other cases at the discretion of the member of the engineering board of the district concerned. An allowance of ten percent for shrink was ordinarily added to the measured volume of embankment, and under the one-way method allowances were made for the swell of rock placed in embankments. The free-haul limits were usually 500 ft. for teams and 5,000 ft. for train haul. The estimated costs of temporary filling trestles were allowed for in the unit prices adopted for grading. Subsidence quantities were included in the inventory when evidence considered satisfactory was found that the underlying material would not support the roadbed, but no allowance for shrink was added to subsidence quantities. Ballast material in excess of that called for by the standard ballast section was classified and priced as grading. The engineering section certified to the land section, the location and extent of areas off the right-of-way estimated as required for borrow pits, for inclusion in the land inventory.

The quantities of clearing and grubbing inventoried were based upon the character of the adjoining and adjacent lands at the date of valuation and not on the character of the land at the time the railroad was constructed, and credit was made in the prices applied for the estimated salvage available from the forest products which would be cleared off under reproduction conditions.

Many differences of opinion between the bureau and the carriers arose from the classification applied by the bureau to material excavated and from the unit prices allowed. The specifications and costs of every available important grading construction project performed during a long period prior to the valuation work were tabulated and considered by the engineers.

Account 4, Underground Power Tubes

Little property was inventoried under Account 4, Underground Power Tubes.

Account 5, Tunnels and Subways

Property chargeable to Account 5, Tunnels and Subways, was inventoried by the roadway parties in terms of the customary construction units.

Account 6, Bridges, Trestles and Culverts

Property in Account 6, Bridges, Trestles and Culverts, was inventoried by the bridge branch, except small culverts which were inventoried by the roadway parties. The location and a description of each important bridge was shown in the engineering reports with the inventory quantities as computed for each bridge and the unit prices allowed. Less detail was shown for unimportant structures, and like items of the inventory of trestles and culverts were combined into totals for each pricing section.

Account 7, Elevated Structures

The relatively small amount of property in Account 7, Elevated Structures, was inventoried by the bridge branch.

Account 8, Ties

Crosstie quantities were computed from tie counts on two sections of track in each mile, each section at least 600 ft. long, with the number of ties of each kind and class in these sections and the type of treatment, if any, recorded. Allowance was made for the lengths occupied by switch and bridge ties, and the number of ties in yards was based on complete or partial counts. Switch ties were inventoried by sets where standards were in use, and bridge ties by count. Ties in stock and scattered along the track for renewals were included in material and supplies.

Ties were priced in accordance with the recommendation of the engineering board that the unit price for each kind, class and size of tie include the price f. o. b. originating point; inspection at not more than two cents per tie; cost of treatment including handling and insurance; commercial freight to the line of the carrier under inventory; construction haul to the assumed location of material yard at five mills per ton mile; and material yard expense including unloading, piling and reloading, car demurrage and other expense at three cents per cross tie and 50 cents (later increased to $1) per M. b. m. of bridge and switch ties. The recommendation of the board that an allowance of one percent be made for loss and waste was disapproved. No allowance was made for interest on treated ties held for seasoning.

The protests of the carriers were more often directed against the sources of ties and the methods of distribution assumed by the bureau for the reproduction program, and the unit prices allowed, than against the quantities inventoried. The commission overruled claims advanced by some carriers for allowances for loss and waste and for interest on ties in addition to the interest during construction computed in accordance with the adopted rule. Application of the "50 percent rule" of Memorandum 226 in depreciating ties in cases where the annual tie renewals were considered as having reached a degree of uniformity, was contested by some carriers.

Account 9, Rails

Rail quantities in gross tons were computed at the pattern weights of the sections from the chained lengths of tracks as measured by the roadway field parties, allowance being made for switch, frog and crossing deductions. Distinction was made between Bessemer and open hearth rail, between which there was a price differential in the 1910-1914 pricing period. The assigned unit prices were intended to include the base price at the rail mill, cost of inspection, commercial freight to the line, company haul on the line to the assumed material yard, and material yard expense, with appropriate allowances for rail furnished to special specifications.

The recommendation of the engineering board in Memorandum 226, which was approved by the director and upheld by the commission, that rail be considered as having two cycles of life, from new to relay, and from relay to scrap, except in the case of new rail initially laid in sidetracks, was very generally objected to by the railroads in their protests against the tentative valuations. Under the two-cycle rule, rail which had been purchased new and subsequently transferred in location as from main track to sidetrack was given a unit price in the cost of reproduction estimates as relay rail. In the case of most carriers this resulted in a substantial decrease in the cost of reproduction new of the rail account under that which would have resulted from pricing such rail as new, but the cost of reproduction less depreciation was not greatly affected as the condition percent was higher as relay rail.

Account 10, Other Track Material

The time required for the field inventory and pricing of the large number of items of small unit cost making up Account 10, Other Track Material, which includes track fastenings, crossings, frogs, switches and miscellaneous track material, was high in relation to the cost of reproduction of the account and was a matter of concern to the director and the engineering board, but no satisfactory way of substantially reducing such time was developed. Allowances for loss and waste of three percent on track spikes, one percent on track bolts, and two percent on nutlocks and anglebars were added to the quantities inventoried, and estimated material yard expense at the rate of 50 cents per net ton of material was included in the unit prices to cover the cost of unloading material from cars, storing, handling, reloading and of maintaining the material yard.

Account 11, Ballast

Ballast was a troublesome and controversial account and the methods used by the bureau in reporting ballast did not become standardized and uniform for a long period. The quantities of each kind of ballast were inventoried by the roadway parties from the cross-section notes and the carriers' standard ballast sections, the depths of ballast being determined by test holes excavated in the roadbed at intervals not exceeding 1,000 ft. on main line and as considered necessary in yards. Allowance was made for the displacement of ties imbedded in the ballast and a 10 percent allowance was added to the measured ballast quantities for shrinkage. Ballast material in excess of two feet below the bottom of ties was ordinarily classed as excess ballast material and priced as common excavation. In some instances carriers with heavy traffic and fast trains had constructed certain sections of road under standard plans with three feet of ballast, and under such conditions the actual amount of ballast in place was allowed as ballast.

The recommendations of the engineering board that company haul rates be used for ballast hauled over subsidiary lines and that the cost of cinder ballast produced by a carrier under inventory be established at 15 cents per cubic yard plus 5 cents for unloading, but that the cost of cinders purchased from outside parties be based on the amounts paid, were approved by the director, and its recommended mileage scale for computing the cost of haul was approved as a maximum.

Ballast items in the inventory were quite generally protested by the carriers, but the commission uniformly upheld the practice of the bureau in pricing cinders produced by a carrier at substantially the cost of loading plus haul and unloading, in allowing only ten percent for shrinkage, in deducting depreciation, and in making no allowance for salvage value in cumputing the cost of reproduction less depreciation. The bureau's estimated reproduction prices and its assumptions as to sources of ballast and as to the character and cost of haul were other subjects of protest.

Account 12, Track Laying and Surfacing

Track laying and surfacing is a labor account to which are chargeable the costs of distributing, laying and adjusting ties, rails and other track material and the cost of the labor of placing ballast in tracks. The engineering board drew up rules to govern the pricing of the account, recommended that the depreciation applied to track laying and surfacing be the weighted average of that applied to ties, rails, other track material and ballast, and submitted a schedule of prices, containing minimum and maximum prices for the principal items, to apply under conditions that were normal and ordinary. These recommendations of the board were approved by the director. The prices recommended by the board were intended to be sufficient to cover the cost of reproducing the track in such condition that commercial operation of the railroad could be begun, but not in the seasoned condition of track which had been in use sufficiently long to permit the operation of high-speed trains.

In conferences with a committee representing the carriers the director attempted to reach an agreement as to unit reproduction costs for this account. Agreement was reached as to the classes of work assumed to be included in the several items of the inventories, substantially agreeing with and adding to the rules previously recommended by the engineering board, but no agreement as to prices was reached.

The bureau's prices for track laying and surfacing were vigorously assailed by many carriers in their protests and at the hearings, the principal point of difference being the omission by the bureau of the cost of seasoning track, which is an operating charge in accordance with the commission's classification of accounts but which the carriers contended should be considered a capital charge for valuation purposes under the theory of reproduction which was being followed. The commission upheld the bureau in this controversy.

Account 13, Right-of-Way Fences

Fences were inventoried by the roadway parties. The legal ownership of fences on right-of-way lines presented some difficulties, but it was usually possible for the bureau's field parties and the carriers' representatives to reach agreements as to the division of ownership and few claims for fencing omitted from the inventory were made by carriers in their protests.

Account 14, Snow and Sand Fences and Snowsheds

Important snowsheds were inventoried by the bridge parties, minor structures and fences by the roadway parties.

Account 15, Crossings and Signs

The structures at overgrade and undergrade crossings were inventoried by the bridge branch and other items in Account 15 by the roadway branch. Many complex questions relative to the division of ownership of the property at crossings arose in connection with the inventory of such property.

It had long been common practice in the United States for a railroad under construction to pay all costs in connection with the crossing of its line with that of an established railroad, including, in the case of separate-grade crossings, the cost of depressing or elevating the tracks of the senior carrier for such distances as might be necessary on each side of the crossing. However, in January, 1916, the director instructed the engineering board to follow, in its inventory of crossings, an opinion of the chief counsel of the Commission which was in substance that the apportionment between carriers should be in accordance with ownership; that a carrier owns all property on its right-of-way; that interlockers should be divided on the basis of operated units; that property in intersections should be inventoried to the exclusive user; and that other property should be apportioned equally. This instruction as to the division of ownership was substantially in accordance with previous recommendations of the engineering board and of the advisory board. The Director further instructed the board that in the case of a crossing of a railroad under inventory with the line of a private or electric railway not a common carrier subject to valuation, there should be inventoried to the carrier as a part of its reproduction cost whatever it in fact did to provide or secure the crossing.

In February, 1919, the engineering board recommended that in the light of experience to date there should be inventoried to each carrier at a railroad crossing that property or proportion of property the carrier had paid for, for which reimbursement had not been made. This recommendation was a material change from that made by the board in October, 1915, but the change was not approved.

The rule followed denied to the junior carriers under valuation the costs incurred at crossings off their rights-of-way in the cost of reproduction estimates, although such costs were includible in original cost and were so reported in the relatively few instances where findings of original cost were made. Many protests were directed against this rule by the carriers, but the commission upheld the bureau's practice and stated in its valuation report on the *Winston-Salem Southbound Railway Company*, 75 I. C. C. 187, 194:

> The method followed * * * does in fact contemplate the assumed existence of the railroads as crossed, and gives full credit in the cost of reproduction estimates for whatever is shown to be owned by a carrier, or occupied or used by it, while showing, as a historical fact for whatever it may be worth, the expenditures in fact made by the carrier in original construction. The method commends itself as involving the minimum of conjecture, and as the only plan which in all its aspects is feasible and certain in practical application.

The apportionment of the cost of reproduction of crossings of railroads and highways was complicated by construction by the carriers off their rights-of-way, by damages paid to abutting property owners, and by payments for such crossings made by public authority, especially in connection with structures erected for the elimination of grade crossings. The practice of the bureau, as approved by the commission, is summed up in the final value report on the *Texas Midland Railroad*, 75 I. C. C. 1, 116, as follows:

> It often happens that in the construction of a railroad the location of a public highway has been changed. Nothing is included in the reproduction estimate for the making of this change. Allowance is made for whatever structure has been provided by the carrier for the crossing of the highway, whether that structure is on or off the right-of-way, but it is assumed that the location of the highway would be as it now exists.
>
> The foregoing paragraph applies in case of a highway crossing which has been constructed by the carrier. It frequently happens that highway crossings at grade are eliminated by providing an undergrade or overgrade highway. This may be by state statute or municipal ordinance, and it sometimes happens that the state or the municipality, or in some instances both, contribute to the cost of eliminating the crossing. In such case the carrier under the accounting rules of the commission carries for the most part into Account 15, crossings and signs, the amount which it has in fact expended in the elimination of the grade crossing. In showing cost of reproduction it is assumed that the present undergrade or overgrade crossing would be reproduced as it was produced, and when those portions of the work which were involved in the elimination of the crossing can be clearly distinguished from the rest of the railroad, there is shown in our reproduction estimate under Account 15 the amount paid by the carrier.
>
> It sometimes happens that quantities can not be identified so as properly to comply with the above rule, and in such cases the actual quantities which are found at the present time upon the carrier's right of way are placed and priced in the engineering inventory. If the carrier conceives that it is entitled as part of its reproduction cost to anything in addition to this, it can file its claim, which will be disposed of as justice seems to require in each individual instance.

Account 16, Station and Office Buildings

Buildings in Account 16 and in other accounts were inventoried by the building branch. Buildings were shown individually on the engineering reports, the location, brief description, type of construction, and dimensions being given. A uniform method of pricing buildings was not adopted, the director having ruled that the members of the board might use, at their discretion, either square foot or cubic foot unit prices. Each district developed types applicable to buildings of ordinary construction, and unit prices to fit such types, but buildings differing substantially from the adopted types were priced by the bill of materials method. Plumbing, heating, lighting and furniture and fixtures were separately shown.

Account 17, Roadway Buildings

For Roadway buildings see Account 16. Conforming to an opinion of the chief counsel of the commission which was approved by the director, dwellings owned by carriers and occupied by employees were inventoried as carrier property only when it was shown that scarcity of accommodations in the vicinity made the provision of such dwellings necessary; otherwise they were inventoried as property not used in transportation service.

Account 18, Water Stations

See Account 16.

Account 19, Fuel Stations

Fuel stations were normally assigned to the bridge branch for inventory but in some instances were taken by the building parties. Location, type, capacity and essential dimensions were reported.

Account 20, Shops and Enginehouses

See Account 16.

Account 21, Grain Elevators

See Account 16.

Account 22, Storage Warehouses

See Account 16.

Account 23, Wharves and Docks

Wharves and docks were inventoried by the bridge branch and individually reported on the engineering reports with the location, description, dimensions and quantities of the several classes of materials appearing for each. Buildings on wharves were inventoried by the building branch as outlined under Account 16.

Account 24, Coal and Ore Wharves

See Account 23.

Account 25, Gas Producing Plants

See Account 44.

Account 26, Telegraph and Telephone Lines

Telegraph and telephone lines were inventoried by the telegraph and telephone branch. The communications companies were also common carriers and under valuation by the commission, and on much of the railroad mileage these companies owned parallel lines and also had interests in the property used for the transaction of railroad business; the field parties usually inventoried all such property while engaged in the railroad inventory to avoid covering the same ground twice.

There was much dispute as to the ownership and use of telegraph and telephone property in which both the railroads and the telegraph companies claimed interests. The contracts between these companies in many instances provided that the railroad companies should pay part of the cost of the property either in cash or in labor for its erection but were not conclusive as to ownership, and the contract arrangements as to the use of wires by the railroads were of various forms to suit the conditions of the individual cases. Where the railroad and telegraph companies were able to agree as to ownership the property was inventoried to the agreed owner; where agreement was reached that property was jointly owned it was so inventoried and the agreed proportion of reproduction cost allocated to each owner; but all wholly owned property was inventoried as wholly used by the owner unless exclusively used by other than the owner.

In the tentative valuations served on the Texas Midland Railroad and the Kansas City Southern Railroad, these being among the first of such valuations served, there were inventoried to the railroads only such telegraph lines as were owned by them, with no credit given for expenditures made by the railroads in connection with lines deemed as owned by the telegraph company. The railroads protested these omissions, and the commission ruled that the estimated cost of such work at prices as of the pricing period should be added to the cost of reproduction new of the account, on the assumption that telegraph lines are necessary in the conduct of railroad business and that under reproduction the railroads would perform the same amount of work as they did in the original construction.

This ruling was questioned by interested parties and the commission assigned the question of ownership of these lines for argument, as a result of which is reversed its position in the Texas Midland and Kansas City Southern cases and found, in *Ex Parte No. 42*, 84 I. C. C. 1, that where a railroad company had contributed toward the construction of telegraph property under a contract which provided that the property when constructed should belong to and form a part of the general telegraph system of the telegraph company and be used by both companies during a specified period of time, the contribution simply constituted a partial payment in advance on account of services to be performed and facilities to be furnished under the contract to the railroad company by the telegraph company during the life of the contract, and that no part of the property should be inventoried as owned and used by the railroad company.

The Western Union Telegraph Company, having its telegraph lines along many of the railroad properties and having close contractual relations involving the ownership and use of telegraph facilities with those railroads, was permitted to intervene in many of the valuation hearings on steam railroad properties and was represented by counsel at such hearings.

Account 27, Signals and Interlockers

Signals and interlocking apparatus were inventoried by the signal branch, buildings chargeable to this account by the building branch, signal bridges by the bridge branch, and machinery, if extensive, by the mechanical branch.

A greater degree of agreement was reached between the bureau and the carriers as to the inventory and pricing of signals and interlocking apparatus than in the case of any other class of property. Conferences between a special committee of the Presidents' Conference Committee, representing the carriers, and the signal engineers of the bureau and with the director and his advisors were followed by the appointment of a joint committee which prepared an "omnibus" in which the catalog references and agreed weights and reproduction prices of about 7,200 items of interlocking and signal material were listed, with percentages to be added to the material costs for freight based on a block and zone plan, and percentages to be applied to cover the cost of installation. The agreement did not extend to buildings, signal bridges, crossing gates and machinery.

The director ruled that interlockers at railroad crossings should be inventoried to the owners of the property when the carriers concerned agreed as to such ownership. This ruling was followed by a recommendation of the engineering board, approved by the director and confirmed by an opinion of the chief counsel, that when the carriers were unable to agree on the proper division of ownership the reproduction cost of the interlocking should be apportioned to the carriers on the basis of the operating units of the interlocking used by each.

Account 28, Power Dams, Canals and Pipe Lines

Account 28 was assigned to the bridge branch for inventory.

Account 29, Power Plant Buildings

See Account 16.

Account 30, Power Substation Buildings

See Account 16.

Account 31, Power Transmission Systems

See Account 32.

Account 32, Power Distribution Systems

The property in Accounts 31, 32, 33 and 34 was inventoried by the mechanical and electrical branch. Included in these accounts are third rail and trolley systems of electrically operated railroads and electric and compressed air distribution systems. In the Eastern district separate electrical parties were organized for the inventory and inspection of the considerable amount of such property, including electric locomotives, in that district, but in the other districts the mechanical parties did this work.

Account 33, Power Line Poles and Fixtures

See Account 32.

Account 34, Underground Conduits

See Account 32.

Account 35, Miscellaneous Structures

See Account 16.

Account 36, Paving

Paving about tracks in public highways through which carriers' tracks are laid longitudinally is chargeable to this account and was inventoried by the roadway parties.

Account 37, Roadway Machines

An inventory and the cost of roadway machines was furnished to the bureau by the carriers in their returns to Valuation Order 8. The inventory was verified by the mechanical field parties and the more important units and many of the small units inspected for condition.

Account 38, Roadway Small Tools

Schedules of roadway small tools were usually furnished by the carriers and verified by the roadway parties.

Account 39, Assessments for Public Improvements

Schedules of assessments paid by the carriers were filed by the carriers and verified by the field accountants. A ruling of the director that assessments should not be included in reproduction costs was upheld by the commission; this omission was the subject of many protests by the carriers. Physical property used in transportation service which was constructed by the carriers in lieu of payments of specific sums for assessments was, however, included in the inventories, in accordance with a recommendation of the engineering board.

Account 40, Revenues and Operating Expenses During Construction

Accounts 40, 41 and 42 are provided in the classification of investment for accounting entries as indicated by the titles of the accounts. The net charges to these accounts appearing in carriers' books on the date of valuation were shown in the summaries of investment account appearing in the reports of the accounting section, but no physical property inventoried by the engineering section was classified to these accounts.

Account 41, Cost of Road Purchased

See Account 40.

Account 42, Reconstruction of Road Purchased

See Account 40.

Account 43, Other Expenditures—Road

Account 43 is provided in the classification of investment to include charges incident to construction but not assignable to specific items of property, such as the cost of transportation of men or materials over a carrier's own line, amounts paid for rent and repairs of equipment and for injuries to persons, and analogous items. In the estimates made by the bureau of cost of reproduction of road and equipment property all costs were considered assignable to specific items and it was not necessary to make use of Account 43.

Account 44, Shop Machinery

Machinery and apparatus in Accounts 25, 44, 45 and 46, and on special request, machinery in accounts assigned to other branches, were inventoried by mechanical and electrical parties. The commission issued Valuation Order 8 on November 21, 1914, requiring carriers to file schedules of roadway machines, machinery and equipment, the schedules comprising a descriptive section, or register of equipment, and an accounting section, or report of original cost to date. When available in advance of the field inspection, the register of equipment provided an inventory of the property which was checked by the field parties. In many instances it was found more convenient to have the inventory of machinery prepared in advance by the carrier in another form, as on the bureau's field forms, which, after checking by the field parties, were used to prepare the formal returns to Valuation Order 8.

Costs of reproduction of home-made tools and devices were usually estimated by the field parties jointly with the carriers' representatives. In the engineering reports fixed machines were individually listed, including with each machine its foundation and wiring to and including the controlling switch; minor machines and small tools were reported in groups or lots for each shop or location.

Account 45, Power Plant Machinery

See Account 44.

Account 46, Power Substation Apparatus

See Account 44.

Account 47, Unapplied Construction Material and Supplies

Account 47 makes provision in the investment account for the cost of material and supplies, located at the point of use and charged out of the material and supplies account, which have been purchased for projected new roads and road extensions, the purpose of the account being to exclude such costs from current assets. By instruction of the director, such material and supplies were not included in the engineering inventory.

Account 51, Steam Locomotives

Each locomotive was inspected by motive power inspectors of the mechanical branch and the service condition estimated in percent separately for the boiler, engine underframe, running gear, tender trucks, tender underframe and tank, from which the weighted percent condition of the locomotive was determined in an office computation. Locomotives were shown on the engineering reports by pricing groups consisting of series of similar units.

Cost data compiled from the carriers' returns to Valuation Order 8 and price trends and costs per pound obtained from locomotive builders were the base of the estimated reproduction costs. Original cost trended to the 1914 pricing period was first used for pricing locomotives, on the recommendation of the engineering board; subsequently a method of pricing by the pound of total light weight was developed in co-operation with a committee representing the carriers, the committee substantially agreeing with the method adopted but not with the prices used. Pricing curves showing the relationship of normal 1914 reproduction costs per pound of total light weight to weight were prepared for "plain" locomotives having few and simple specialties; from these curves base prices f. o. b. builders' works were computed, to which were added the estimated extra costs of the specialties found on the locomotives being priced and not included in the "plain" price, and the costs of inspection, freight, messenger service, setting up and breaking in, and fixtures, tools and accessories to fit the locomotives for service, to obtain the reproduction costs adopted.

Account 52, Other Locomotives

Electric, compressed air and internal combustion engine driven locomotives were inventoried by the mechanical and electrical parties, the method followed being similar to that used for steam locomotives. Reproduction costs were usually based on original costs trended.

Account 53, Freight-Train Cars

Car inspectors of the mechanical branch ordinarily inspected for condition not less than ten percent of the freight cars in each series of similar cars, the existence of cars not inspected being verified from the car movement records of the railroads. Service condition in percent was separately estimated for the bodies, underframes and trucks, from which weighted averages per car and averages for the series were computed. The pricing of cars was based on costs compiled from Valuation Order 8 returns and cost data obtained from car builders and other sources.

Account 54, Passenger-Train Cars

Practically all passenger cars were inspected by car inspectors of the mechanical and electrical branch; depreciation was estimated separately for the body, underframe and trucks of cars, weighted and averaged for pricing groups of similar cars; pricing was based on cost data compiled from carriers' returns to Valuation Order 8.

Account 55, Motor Equipment of Cars

Motor equipment for cars was inspected by the mechanical and electrical parties and the service condition ascertained separately for the principal parts. The difficulty of apportioning the costs of self-propelled cars between accounts prompted the engineering board to recommend that self-propelled passenger cars including their motor equipment be assigned to the car account, retaining in Account 55 only such equipment as was used on cars not self-propelled. This recommendation was approved by the director.

Account 56, Floating Equipment

The floating equipment owned by the railroads under inventory, consisting principally of tugs, barges, floats and lighters at port terminals, car ferries and other equipment on the Great Lakes, and river equipment, was assigned to the mechanical and electrical branch for inventory. The reproduction prices adopted for this equipment were in general based on original costs as reported in carriers' returns to Valuation Order 8, trended to the 1914 level.

Account 57, Work Equipment

Rail work equipment and floating work equipment, comprising units used in company service and not for the transportation of revenue passengers or freight, were inventoried and priced by the mechanical and electrical branch as were units of similar construction in equipment accounts 51 to 56.

Account 58, Miscellaneous Equipment

The carriers' schedules of miscellaneous equipment, including horses and harness, wagons, automobiles and other highway vehicles, were verified by the mechanical field parties and the service condition of the units estimated. Prices were in general based on original cost as reported in Valuation Order 8 returns.

Accounts 71 to 75 and 77, General Expenditures Except Interest During Construction

Accounts 71 to 75 and Account 77 were treated as a single group in the reproduction estimates, and include organization expenses (71), general officers and clerks (72), law (73), stationery and printing (74), taxes (75), and other expenditures—general (77); they are designed to include expenditures not assignable to specific items of property made in connection with the acquisition and construction of original road and equipment and with extensions, additions and betterments to road and equipment property.

The bureau made a study of overhead costs on 121 railroad construction projects in different sections of the country collected by accountants of its accounting section and referred to herein under Account 1, engineering; a summary of this study, the so-called Brown exhibit, was introduced into the record in a number of valuation cases, and was relied on by the bureau to support its estimates of general expenditures. The ratios of the recorded costs of general expenditures except interest to the corresponding totals of the road accounts except land show wide variations, to which several factors contribute; the investment accounts of the older railroads were not kept in a uniform manner during the construction periods; many of the more recently constructed lines were built as subsidiaries of existing railroads and part of the costs properly chargeable to general expenditures was absorbed by the parent companies; in the classification of investment in effect prior to July 1, 1914, the items includible in general expenditures were different in certain respects from those so includible under the 1914 classification under which the estimates of reproduction costs were classified in the valuation reports; and the charges as made include costs incurred in connection with the acquirement of land which under the valuation theory adopted by the commission were not includible in reproduction estimates.

The director instructed the engineering board in September, 1916, to compute the cost of reproduction new of general expenditures except interest during construction at 1½ percent of the total cost of reproduction new of the road accounts except land and to call to his attention cases considered abnormal. Subsequently the director further instructed the board to depreciate general expenditures at the weighted average percentage of the road accounts except land used as the base. The 1½ percent rule was not allowed in the tentative valuation on the Texas Midland Railroad, and in its decision in that case the commission changed the allowance for general expenditures to 1½ percent of the road accounts except land and added the general rule that the actual costs of charter fees should be added to the 1½ percent allowances when such fees were more than nominal in amount. However, in a memorandum dated September 18, 1919, the director instructed the board that no allowance for charter fees should be added to the amount computed at 1½ percent.

For several years thereafter the 1½ percent rule was followed in substantially all valuation cases decided, but beginning with the decision in *Great Western Railway Company,* 125 I.C.C. 674, decided June 15, 1927, departures from the rule were numerous, and in its report on *Pennsylvania Railroad Company,* 22 Val. Rep. 1, 105, the commission said: "We formerly computed general expenditures by the practically uniform application of a percentage of 1.5. * * * After further consideration of the matter we concluded that a sliding scale should be used." No definite rule for the application of the sliding scale has been made public. The allowances made to the New York Central Railroad, to the Pennsylvania Railroad and to the Pittsburgh, Cincinnati, Chicago & St. Louis Railway, a part of the Pennsylvania System, were reduced by the commission from the 1½ percent allowed in their tentative valuations to 1 percent; the allowances to most of the remaining railroads except certain smaller carriers remained at the 1½ percent previously used; a considerable number of small carriers and terminal properties were given allowances of 2 percent; in a few instances 2½ percent was used; and in about a dozen instances the allowance was 3 percent.

The engineering board did not recommend the adoption of the 1½ percent rule. The accounting records of the carriers during original construction over a period of many years had not been kept in a uniform manner and it was impossible to ascertain the actual cost except in a small number of cases of comparatively short roads. A large part of the railroad mileage of the country had been constructed by parent roads which furnished general services in connection with organization, financing and construction for which no charges were made on the books of the subsidiary companies. It is improper to apply a single percentage to each and every one of the 1,900 railroads in the United States, and variable percentages should be used depending upon the requirements of state laws and local conditions affecting construction.

The estimates of cost of reproduction made by the bureau and the final values found by the commission contained no specific allowances for the costs of financing, but such facts as were ascertainable as to the actual expenditures made by the carriers for this purpose during construction were contained in the accounting reports prepared by the accounting section. The views of the commission and the practice followed are illustrated in the following extracts from the statement of methods contained in Appendix 3 to the final value report on the *Texas Midland Railroad,* 75 I.C.C. 153–155:

> The cost of obtaining the money with which to finance the construction of a railroad has been frequently and perhaps usually treated as an overhead. After mature consideration, it has been thought best in reporting cost of reproduction new to show nothing on this account as such but to include any necessary charge of that character in the interest rate.
>
> Ordinarily a railroad corporation finally obtains the money with which to defray the expense of constructing its property by the sale of stock and bonds * * * . Whatever method is adopted would involve a certain amount of expense. * * * The most important factor in determining the cost of obtaining the money and the rate to be paid for the same would be the credit of the borrower. * * *
>
> It was felt at the outset that it might be necessary to determine in each case the cost of obtaining this money; that is, that inquiry must be made into the credit of the company and the circumstances which would surround its financing. Further reflection, however, showed that this would be an almost impossible task, and that the result would be misleading rather than informing. On the whole it seemed best to assume that the credit available when the property was being reproduced was in all cases good and the same; that money would be obtained at the same rate and supplies purchased on equally advantageous terms. Upon no other theory would the cost of reproducing the different properties be fairly comparable.
>
> This being settled the next question is as to the rate of interest to be adopted. Six percent is the legal rate of interest in a large section of this country where no other rate is specified. An examination of the sale of bonds of various kinds for the five years preceding June 30, 1914, led to the belief that this rate would be ample to cover not only the interest on the money but any brokerage which would usually be charged for the obtaining of the money. It has been assumed, therefore, that at six percent whatever money is needed can be obtained, and that this rate of interest will cover the entire cost of obtaining the money.
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> * * *
>
> It should be further borne in mind that engineering reports do not attempt to place a final value upon properties. There may be facts in the financial history of a corporation which would make it just to consider the cost to that road of obtaining money in the determination of its final value. The financial history of every corporation is fully dealt with in the accounting report. The engineering report deals merely with the physical property of the carrier, and in estimating the cost of reproducing that property new it is assumed that the money can be had for six percent without additional cost and without inquiring how it is to be obtained.

The carriers generally protested the allowances made in the tentative valuations for general expenditures except interest. A subcommittee of the Western Group Cost Data Committee of the Presidents' Conference Committee analyzed the cost data contained in the Brown exhibit and added data from other projects, preparing the so-called Burton exhibit which was introduced into the record in a number of cases.

Account 76, Interest During Construction

The construction period used in the computation of interest during construction was defined as that period within which it was estimated that the work of construction might be economically done, with unusual delays eliminated and utilizing all means of transportation existing on the date of valuation. The construction periods were estimated by the district engineering staffs with the approval of the members of the engineering board; the board did not recommend any rules for the determination of these periods. In the case of large carriers construction periods were separately assigned to those sections of the lines which it was considered might economically be turned over to operation either progressively, or independently of the other sections.

The rule set by the commission for the computation of interest during construction was that interest should be computed at the rate of six percent per year for one-half the construction period, plus three months (i. e., for a 12 months' construction period, the interest period should be 9 months), on the total of the road and general expenditures accounts, except on land and interest during construction, and for a period of 3 months on the total of the equipment accounts.

Pricing of Inventories

The cost of reproduction estimates of all of the original basic valuations was based on the so-called 1914 normal prices, or 1910–1914 prices, regardless of the dates of valuation of the carriers; the unit prices used were intended to represent costs prevailing in the 5-year period from 1910 to 1914, or, to a limited extent, in the 10-year period from 1905 to 1914. The adoption of June 30, 1914, as the pricing date for all of the original valuations was in a sense accidental. The field inventory and the assembling of cost data were begun in 1914, and the use of a common pricing date for all carriers regardless of the dates as of which the inventories were prepared was the only practicable plan.

The assembling of cost data was begun in each district office, and as the work progressed it assumed such importance that a cost branch was organized in each district with a central cost branch office in Washington. The costs studied by the cost branch were confined principally to roadway and general inventory items, the cost data for such specialized property as bridges, buildings, telegraph and telephone lines, signals, machinery and equipment being collected and studied by the engineers in those branches. The establishment of the proper units for inventory and pricing purposes was a joint function of the inventory forces and cost branches. Commercial units, or the units commonly used in construction estimates, were adopted for the principal inventory items. Special items, fences, small structures, telegraph and telephone property, and signals were reduced to types for inventory and pricing purposes in so far as practicable.

The unit prices adopted were designed to include all proper costs of doing the work allocated in accordance with the accounts in the classification of investment, including the net cost of materials at points of manufacture, commercial freight, company haul, handling, material yard expense, placing, insurance, incidental expenses and contractors' overhead and profit.

By orders of the commission, carriers were required to file schedules listing the principal representative purchases of materials and their costs, and the labor rates in effect, in the pricing period. These schedules included all of the common construction materials and telephone and telegraph materials. The schedules for machinery and equipment required by Valuation Order 8 were not limited to the pricing period but called for reports of original cost to date of all property owned or used on the date of valuation. In addition to the cost data reported in the returns to these orders the bureau obtained much other information on prices and costs from the railroads and from carriers' committees, as well as from manufacturers, contractors, equipment builders, dealers, and other government agencies.

A uniform pricing period was not used for the 121 small carriers inventoried as of 1927 and 1928. Of 95 properties with the valuation date of December 31, 1927, 91 have a stated pricing period of 1923 to 1927, and 4 are priced as of the date of valuation; of 26 properties with valuation date of December 31, 1928, 25 have a stated pricing period of 1923 to 1928 and 1 a stated pricing period of 1923 to 1927.

Engineering Reports

The work of the engineering section was summarized in the form of engineering reports on each carrier prepared in the district offices under the direction of the respective members of the engineering board, or in the report branch of the engineering section of the bureau after consolidation of the district offices in Washington. The reports were typewritten on 11-in. by 17-in. paper, one copy being carbon-backed so that blueprint copies might be made therefrom, and varied in size from a few pages to several thousand pages—that for the Pennslyvania Railroad system exclusive of the Panhandle–Vandalia and some other lines consists of 4,526 pages. Copies were furnished to the carriers concerned.

The reports opened with a map of the railroad, and a title page giving the names of the carriers to which the report applied, the date of the inventory (date of valuation), and the pricing date, which, in the original basic reports was given as: "Prices as of June 30, 1914." These were followed by an explanatory text containing a general description of the railroad; a statement of the mileage and valuation sections; a section describing the characteristics of the country traversed by the line; a description of the property in the principal road accounts; a section on equipment stating the number and kind of units; a statement of the percentages used for engineering and general expenditures and of the lengths of the construction periods assigned; and general information as to the method used in the computation of grading quantities and the allowances for shrinkage and waste.

The explanatory text was followed by a grand summary showing the mileage and cost of reproduction new and cost of reproduction less depreciation by the classes, wholly owned and used, wholly used but not owned, jointly owned and used, jointly owned but not used, wholly owned but jointly used, jointly owned but wholly used, and total owned and total used, and summaries of the cost of reproduction new and cost of reproduction less depreciation by primary investment accounts. The engineering inventory included only carrier property—that used in transportation service, abandoned property being omitted and non-carrier property included in the land reports. The designations "not owned" and "not used" refer to the ownership and use of carrier property by the railroad being reported on, and the names of the owners and users other than the carrier and in the case of joint property the respective proportions of ownership and use were stated in the headings of the detailed inventory sections.

The detailed inventory, priced and extended, followed the summaries, with a summary sheet containing the totals by primary investment accounts for each property group. Each property group was limited to property within one state, of a single class of ownership and use, except that a carrier's portion of jointly owned or jointly used minor facilities was included with the wholly owned or wholly used property. Equipment was not segregated by states but was reported as unallocated. The detailed inventory sheets contained, for each item, its location if a structure or machine not grouped with similar items at various locations, the character of property and description, the condition percent (ratio of remaining service life to total service life), the percent of cost new (ratio of cost of reproduction less depreciation to cost of reproduction new), the unit in which quantity was expressed, the number of units, the cost of reproduction per unit (unit price), the cost of reproduction new, total (product of number of units and unit price), and cost of reproduction less depreciation (the cost of reproduction new less scrap or salvage value, multiplied by condition percent, plus scrap or salvage value).

The Land Section

The act required the commission to ascertain and report as to common carrier lands separately from improvements, the original cost as of the time of dedication to public use, the present value, and the original and present cost of condemnation and damages, or of purchase in excess of original cost or present value, and as to noncarrier property, the original cost, the present value, and an analysis of the methods employed. The engineering board recommended to the director that the duty and responsibility of appraising railroad lands be assigned to the board, pointing out that in railroad practice engineers survey the land, prepare deeds, and either purchase the land direct or employ agents who act under their instructions, and thus the engineers are entirely familiar with the conditions under which land is acquired by carriers. This recommendation was not followed, however, and a land section was organized under the direction of a supervisor of land appraisals. Although the land and engineering sections were independent, they worked in close co-operation in such matters as the classification of property and the avoidance of either omissions or duplications in the inventory.

The field appraisal was made in accordance with printed *Instructions Pertaining to Land Appraisals—Field*, issued by the supervisor of land appraisals, and the land appraisers were under the direction of the valuation attorney in each district office. The inventory was prepared from schedules of land parcels furnished by the carriers to the bureau in their returns to the commission's Valuation Order 7 showing for each numbered parcel pertinent information as to the deed or instrument under which the parcel was acquired, area, consideration, date dedicated to public use, and cost, and for portions of parcels sold the dates and considerations, and also pertinent data relative to rights claimed by the carriers. These schedules were checked by the land appraisers as to areas, ownership and classification. For convenience in pricing, the lands in each valuation section on a railroad were subdivided into zones, a zone embracing parcels of substantially similar characteristics and unit value, and to assist in estimating the unit values the land appraisers compiled records of property sales in the vicinity of the lands being valued and obtained opinions as to values in the vicinity from real estate dealers, bankers and others presumed to be acquainted with such values; assessments were often compiled, and were given such weight as was considered proper in the estimates of values. The value of improvements on noncarrier land was included in the values reported, and on occasion the assistance of the engineering section was enlisted for appraisal of such structures.

Estimated Present Market Values

The present values assigned by the land appraisers were the estimated present market values of similar adjacent and adjoining lands, and were as of the respective dates of valuation of the carriers and not as of the pricing period used in the estimates of cost of reproduction, a discrepancy which, in the words of the Commission repeated in many valuation reports, "will be removed when we adjust to later dates, in accordance with the requirements of the valuation act, the final values herein reported." Present value as defined by the director is quoted as follows in the final value report on the *Texas Midland Railroad*, 75 I. C. C. 1, 53:

> Present value * * * is arrived at by ascertaining the number of acres of land owned or used by the carrier for its purposes as a common carrier and multiplying this acreage by a market value determined from the present market value of similar adjacent and adjoining lands. Due allowance is made for any peculiar value which may attach by reason of the peculiar adaptability of the land to railroad use.
>
> Nothing is included for the expense of acquisition, nor for severance damages, nor for interest during construction.

Rights in the public domain were assigned a present value equal to the amounts paid for such rights; rights in private lands, including such rights in lands owned by a state or municipality which could be sold or conveyed, were appraised at the present value of the lands. The rule adopted and approved by the commission as to land in streets and highways used for carrier purposes is given in the *Texas Midland Railroad* report, 75 I. C. C. 1, 175, as:

> * * * the carrier * * * is credited with the full value of exclusively occupied land included in vacated streets except when it affirmatively appears that it is not the owner, is credited with land jointly used with the public in highways outside of municipalities unless the carrier's lack of ownership affirmatively appears, and * * * no part of streets in municipalities used jointly with the public is included unless the carrier's ownership is made to appear affirmatively * * *

The valuation amendment of March 1, 1913 required the commission to report the "original and present cost of condemnation and damages or of purchase in excess of such original cost or present value" of common carrier land. Believing that it was practically impossible to report the fact called for, and that the decision of the Supreme Court of the United States in the *Minnesota Rate Cases*, 230 U. S. 352, decided in June, 1913, rendered immaterial the finding even if it could be made, the commission declined to state a figure for excess cost of lands in the early tentative and final valuation reports. The Kansas City Southern Railway Company brought an action of mandamus to require the commission to find and report such excess cost. On March 8, 1920 the Supreme Court held (252 U. S. 178) that the commission was required by the act to find excess cost irrespective of its evidential usefulness as an element of railway value. The commission proceeded in compliance with that decision and reported excess costs of acquisition in tentative valuations served on the carriers until relieved of that requirement by an act approved June 7, 1922. Service of final valuations was deferred in the interval, pending the expected action by Congress on the commission's recommendation that this requirement be stricken from the act.

Form of Reports

The land reports prepared by the land section opened with summaries of the present values of lands arranged by classes of ownership and use, including non-carrier property, and showing the totals by states, and summaries of the values assigned to rights and of land aids, gifts, grants and donations. These were followed by detail sheets for each property group showing the assembly of land zones in a valuation section containing, for each zone and sub-zone, map reference, zone limits (these columns being frequently used for the entry of parcel numbers), name of city or county in which located, area in square feet (for urban land) or in acres (for rural land), the appraiser's unit value, and the present value of the zone. Details of the rights in public domain and in private lands, and of land aids, gifts, grants and donations concluded the report

Land matters were the subject of many protests by the carriers, these being directed to the principles adopted by the commission, especially the omission of severance damages and excess costs of acquisition, to the unit values, under the commission's rules, assigned to zones, and to the classification as non-carrier of lands alleged by the carriers to be used for transportation purposes. As a result of the additional evidence introduced at hearings on the protests or brought to the attention of the land section at joint conferences held prior to the conclusion of the hearings, the commission authorized many changes in classification and unit values but in general adhered throughout the valuation work to the principles laid down in the first valuation reports issued.

The valuation act requires that the commission "shall from time to time, revise and correct its valuations * * * ." The revisions in land values are made in accordance with the published *Outline of Plan for Bringing Land Valuations to December 31, 1927, and Such Other Date or Dates as may be Fixed by the Director of Valuation*, approved by Division 1 of the commission on June 12, 1928. Changes in areas are taken from checked returns made by the carriers to Valuation Order 3, and to keep itself informed of changes in land values a force of appraisers and clerks is kept in the field by the land section, the organization being described in an exhibit prepared by the bureau and introduced into the record in *Ex Parte No. 123, Fifteen Percent Case, 1937–1938, 226* I. C. C. 41, as follows:

> The bureau's field appraisal organization consists of 18 districts covering the United States with headquarters in approximately 50 cities. Within commuting distance of these headquarters is situated nearly 60% of the total railroad land value in the United States. The force within each district has been kept as stable as possible and the majority of them have been located within the same territory for a decade or more, appraising, as occasion required, the more important properties and observing and studying changes in values throughout the districts committed to them. Their attention has been centered on urban real estate at points of concentration of value which include the bulk of railway land value.

The Accounting Section

The accounting section of the bureau was organized to ascertain and report to the commission the information called for by the valuation act derived from the books of account and other records and documents of the carriers, and to co-operate with and assist the engineering and land sections in obtaining accounting data necessary in connection with the work of those sections. The commission appointed a supervisor of accounts as head of this section, to whom reported the five district accountants whose headquarters were at the respective district offices and who supervised the field investigations in the districts.

Accounting Reports

The work of the accounting section is well indicated by the subject headings of the accounting reports which were prepared for each corporation and for predecessor companies as well; these headings, with a brief description of the text thereunder were:

1. Introductory
   Name of company, location, mileage and general information.
2. Corporate history
   Including date and purpose of incorporation of company and its predecessors; date and manner of demise of extinct companies.

3. Development of fixed physical property
   Manner of acquisition of the various sections of road, joint facility arrangements etc.
4. History of corporate financing
   Covering syndicating, banking and other financial arrangements; capital stock; funded debt; receivers' certificates; notes; certificates of indebtedness and advances; increases and decreases in stocks, bonds, or other securities in any reorganization.
5. Results of corporate operations
   Condensed income and profit and loss statements for the operating period and for the year ended with the date of valuation.
6. Investment in road and equipment
   The balance therein, classified, with appropriate comments.
7. Original cost to date of road and equipment
   In such detail as was available and appropriate for the purpose of the report.
8. Improvements on leased railway property
   The amounts, distributed among lessor companies and classified by accounts.
9. Miscellaneous physical property
   Classified by general classes.
10. Investments in other companies
    The total at date of valuation, classified by kinds of securities, with appropriate comments.
11. Aids, gifts, grants and donations
    Analysis of carriers' returns.
12. Material and supplies
    Analysis of balance at date of valuation.
13. Leased railway property
    Description of, and comment on, the property of others used by the carrier, and the property of the carrier used by others.
14. Balance sheet
    As of date of valuation.

Original Cost to Date

The act requires that the reports shall show the original cost to date of each piece of property other than land, and the original cost of lands separately from improvements as of the time of dedication to public use. The ascertainment of these costs was made the responsibility of the accounting section. Experience quickly demonstrated that owing to lack of adequate records, particularly as regards construction prior to 1907, when compliance with the Commission's classification of accounts became mandatory, it would be impossible to report the complete original cost of most of the railroad properties, and that in most instances such original costs as were ascertainable could not be reported in detail in terms of the units used in the cost of reproduction estimates. Carriers' returns to Valuation Orders 7 and 8, schedules of land and of machinery and equipment, respectively, which called for reports of the cost of such property, were verified, and the investment and other records of the carriers examined. The facts thus ascertained were given in the reports by the accounting section, and formed the basis for such findings of original cost as the commission was able to make in its tentative and final valuations. Except in the relatively few instances where more complete data were available, the commission customarily stated in its findings that the actual original cost could not be definitely ascertained, as the necessary records were not available.

Protests by carriers against the commission's original cost findings in the tentative valuations covered a wide range, including the failure to report definite and complete costs, failure to report such costs in detail, failure to include therein material and supplies and cash, failure to include the increased cost of property units replacing original construction, and many specific items peculiar to the properties of the individual protestants.

Aids, Gifts, Grants and Donations

By the valuation act the Commission was required to ascertain and report the amount and value of any aid, gift, grant or donation to a carrier or its predecessors, the amounts received by carriers from sales of portions of land grants, and the amount and value of any concession or allowance made by a carrier to any public authority in consideration of any aid, gift, grant or donation.

Under the commission's accounting classifications the value of a donation or a grant is chargeable to investment, an equivalent credit being made to profit and loss in case of a donation by an individual or company, or to balance sheet account 754, grants in aid of construction, in the case of grants by public authority.

All property owned or used by carriers was inventoried and included in the appropriate classification of reproduction costs or present value regardless of how the property was acquired, and the information required by the act as to aids, gifts, grants and donations was separately reported. Lands, the deeds to which recited merely nominal considerations, were reported as apparent aids in the absence of other proof of payment therefor.

Upon inquiry by the director, the engineering board recommended that carriers be ordered to file schedules of aids, gifts, grants and donations, in addition to the schedules of lands. Such an order was issued by the commission as Valuation Order 16. The accounting section verified and made a classification of these returns.

Working Capital

The commission defined working capital for common-carrier service as including, possibly, three principal parts: (1) The investment in a stock of material and supplies, including only the stock necessary for repairs, maintenance, and the supplying of the carrier's own operating requirements, and excluding scrap or obsolete material and material to be drawn on for additions, betterments and extensions; (2) the invested cash necessary, if any, to pay such outlays, including taxes, incurred in connection with common-carrier service as might fall due prior to the time when the cash received in connection with that service and applicable to such outlays was available, excluding outlays for interest, rent other than joint facility rents, dividends, and expenditures for additions and betterments; and (3) the invested cash necessary, if any, to raise the buffer fund of cash constantly on hand sufficiently to cover amply any recurrent and fluctuating deficiences in the inflow of cash applicable to payments falling due. The Commission held, further, that in no event could it be assumed that the working capital as of valuation date was in excess of the sum of the cash actually on hand and the investment in material and supplies on that date.

The engineering board recommended to the director the principles which should govern the inventory of material and supplies, and that the commission order carriers to make such an inventory as of June 30, 1914, and annually thereafter, but otherwise took no formal action in the matter of working capital. The director ruled that material and supplies account would be handled by the accounting section.

The amounts included by the commission in the final values for material and supplies were in most cases based on the average monthly balances in that account for a period, usually five years, prior to date of valuation, adjusted for scrap and obsolete material and for material carried for addition and betterment work, and further adjusted to the rate of operating expenses at the date of valuation.

Several methods for the determination of working capital were used by the commission at different times or to suit the particular case or the information available. An early method used in many cases was the application of a judgment percentage to the carrier's operating expenses during the year ended on valuation date. The bureau made an analysis of the experience and requirements of Class I, and to a lesser extent Class II carriers, and concluded that on the average, carriers required for working capital, including both cash and material and supplies, about 13.5 percent of one year's operating expenses. This method is first described in some detail in Appendix 3 to the final valuation of the *Cairo, Truman & Southern Railroad Company*, 103 I. C. C. 286, 297, decided October 2, 1925, and the same or a generally similar method appears subsequently in many reports. In the application of this method to a particular road the variations of certain factors as computed for that road from the average factors for the Class I and Class II roads are used to modify the percentage applied to the operating expenses of the carrier under consideration to arrive at its invested working capital.

In another method, first described in detail in Appendix 3 to the final valuation of the *Delray Connecting Railroad Company*, 106 I. C. C. 192, 205, decided December 4, 1925, the carrier's cash requirements are computed from statistics taken from its annual reports to the commission and from its reply to a questionnaire. This method was used in a number of final valuations, and a modification of it is described in Appendix 3 to the final valuation of the *Northampton & Bath Railroad Company*, 149, I. C. C. 244, 263, and is incorporated by reference thereto in many of the subsequently issued valuations. Modifications of these several methods were used in numerous instances.

The methods approved by the commission for the determination of cash working capital resulted in widely divergent findings; for example, in excess of six million dollars for the Baltimore & Ohio Railroad system, but only $310,500 for the Atchison, Topeka & Santa Fe Railway and its leased and affiliated lines. In his partial concurrence in the Santa Fe case, Commissioner Hall said: "I find it difficult to accept the conclusion that such a system as the Santa Fe was or could be operated on valution date with a cash working capital not exceeding $310,000." In the cases of the Wabash Railway Company, the Missouri Pacific Railroad Company, and of other carriers, the Commission's findings were that no cash working capital was required.

Protests against the working capital allowances appearing in the tentative valuations were made by many carriers, especially in those cases where the method used in such computations resulted in a finding materially less than the balance sheet totals of cash and material and supplies as of valuation date. Carriers' claims for amounts in excess of such totals were uniformly denied.

Tentative Valuations

With the engineering, land and accounting reports prepared by the bureau before it, the commission, either as a whole or represented by its Division 1, was in a position to take the next step in the valuation procedure, make its finding of value and serve a tentative valuation on the carrier. With certain exceptions in the case of the first few carriers on whom they were served, the tentative valuations were all similar in general form, each containing a formal notice, a table of contents, and a report. The report opened with general remarks and thereafter was divided into sections (or parts), a section being given to each operating corporation including its leased lines, of a system. Each section opened with a statement giving the location and a general description of the properties, followed by a separate subsection for each corporation. The subsections contained the Commission's findings as to capitalization; results of corporate operations; original cost to date; invesment in road and equipment; improvements on leased railway property; cost of reproduction new; cost of reproduction less depreciation; cost and present value of lands; rights in public domain; rights in private lands; non-carrier property; aids, gifts, grants and donations; material and supplies; and final value. Following these findings there appeared in each section an appendix containing a summary of the engineering report, an appendix containing summaries of the accounting reports on each carrier and its predecessor companies, and unless an analysis of the method for determining working capital was incorporated by reference, an appendix outlining that method. A formal order declaring the report to be the tentative valuation of the carrier concluded the document. The tentative valuations were mimeographed on 8-in. by 12½-in. paper.

The valuation act requires that the commission give notice of tentative valuations not only to the carriers concerned but also to the attorney general of the United States, the governor of any state in which the property valued is located, and to such additional parties as the commission may prescribe, with opportunity given each of them to file protests against the tentative valuations. The additional parties prescribed by the commission for the service of tentative valuations included the railroad commissions of the states in which the carriers operated and other interested parties. The tentative valuations bore the requirement that protests and briefs be served on all parties named in the notices incorporated in the tentative valuations.

Protests and Hearings

By the act, carriers and other parties interested were allowed 30 days from the date of service of the tentative valuations to file their protests thereto. Extensions of time were seldom granted, and in some instances when protests were filed shortly after the expiration of the statutory period the tentative valuations were subsequently declared final without hearings thereon. However, after the first few tentative valuations had been served carriers generally had knowledge of the form adopted by the commission and the principles followed and thus had ample time in which to draft the protest against the principles. The carriers also received preliminary copies of the engineering, land and accounting reports in advance of the service of the tentative valuations, or were otherwise acquainted with the differences between their own estimates and those of the bureau.

The proceedings in valuation cases were carried out in conformity with the rules of practice of the commission. After filing of a protest, the commission set a date for hearing on the matters protested. The hearings were usually held before an examiner of the commission, with witnesses for the carriers and other protestants and for the bureau presenting their testimony. Strict rules of evidence were not observed. At the conclusion of the hearings, briefs and reply briefs were filed. Oral argument followed, before the presiding examiner, or before Division 1 of the commission, or before the full commission, if desired by a protestant and if request therefor was granted, this being discretionary with the commission.

All protested matters were given careful consideration by the commission when supporting evidence was made of record at the hearings. In questions of fact, such as disputed quantities or prices, the bureau either revised its estimates or defended its position on the witness stand, and in the latter case the commission reached its conclusions from the record. The bureau was frequently not upheld by the commission.

In a number of cases testimony respecting matters concerning which the carriers had made no protests was introduced by the bureau in hearings. Objections to the introduction of such testimony, on the grounds that the commission was without authority to make changes in matters not protested without prior service of an amended tentative valuation affording the carriers an opportunity to protest thereto, were overruled by the commission. The commission's authority to correct tentative reports even when protests were not filed, and to reopen proceedings for the consideration of matters not protested was upheld by the Supreme Court of the United States.

Conferences

Following the transfer of the district offices to Washington in November, 1921, carriers which so desired were permitted to confer with the bureau with regard to the preliminary engineering, land and accounting reports and to file informal objections thereto. With the object of further reducing the differences between the carriers and the bureau and reducing the amount of testimony offered at the hearings, the commission, in 1924, by Division 1, authorized the following:

> Voted: That the Bureau of Valuation, under the direction of Commissioner Lewis, be authorized in two cases at the hearing on protest against tentative valuation reports, to hold conferences of experts representing interested parties and the bureau, for the purpose of simplifying the issues, and where possible and not detrimental to the public interest, of arriving at agreements with respect to controverted points, any agreements arrived at to be stipulated for the record.

The *Santa Fe* and the *Panhandle–Vandalia* cases were selected for this test of shortened procedure, and similar procedure was authorized in many subsequent cases. The stipulations arrived at by the conferees were of three classes: (1) Matters as to which there was entire agreement; (2) matters as to which there was agreement regarding the facts, although there was disagreement as to the principles involved; and (3) matters as to which there was no agreement either as to facts or principles. The commission was not bound by stipulations entered into by representatives of the bureau.

At the outset, applications for formal conferences were made by protestants after the cases had been opened for formal hearing. In April, 1926, the commission revised this procedure, and required that applications for conferences should be by motion in writing, stating the questions upon which conference was desired, and filed at the time of filing of the protest against the tentative valuation report.

The conference plan was generally satisfactory to all concerned. In its 1926 Annual Report the commission said:

> * * * Our experience has convinced us that the conference plan has many advantages. It has been followed in numerous cases, including those of several of the most important carriers in the country, and thereby the records have been materially shortened and simplified without sacrifice of any essentials or detriment to the public interest. An increasing number of carriers have indicated their intention of making formal applications for reference of their protests to conference as they come on for hearing. These applications are presented at scheduled hearings and all parties are advised and given like opportunity to be represented in the conferences. In some such cases we have had the advice and assistance of technical representatives of the state commissions.

And in its 1927 Annual Report the commission further states:

> * * * Our impression of the results secured through the use of this procedure has been most favorable.

Final Valuations

Following conclusion of the hearing of a valuation case the presiding examiner made a report of the proceedings to the commission and in due course the commission issued its final valuation of the property of the carrier. The final valuations were printed, and similar in form to the decisions of the commission in other types of proceedings. Advance copies of individual decisions were available. In all but a few cases the final valuations comprised a report followed by an order. The report gave the status of the proceedings, a general description of the properties, and a discussion of protested items and the commission's conclusions thereon, or if no protest had been filed, a statement declaring the tentative valuation to be the final valuation. Concurrences and dissents, if any, concluded the report. The orders of the final valuations were similar to the reports, including the appendices, of the tentative valuations, described hereinbefore, and contained such corrections as were authorized as a result of the hearings on the protests.

The valuation orders of the commission were sustained by the Supreme Court of the United States on appeal, in suits in equity to set aside such orders brought by the *Los Angeles & Salt Lake Railroad Company*, 273 U. S. 299, and *The Kansas City Southern Railway Company*, 275 U. S. 500, both decided in 1927.

The first final valuation issued, that of the *Texas Midland Railroad*, 75 I. C. C. 1, contains in an appendix a statement of the methods employed and of the reasons for the differences between the various cost values reported. This appendix is incorporated by reference in all of the subsequent valuations.

Interstate Commerce Commission Valuation Reports

The decisions of the commission in valuation proceedings are contained in a series of valuation reports. The basic valuations of all steam railroad properties including those with 1927-1928 valuation dates are included in volumes 1 to 46 of these reports; Vol. 47 contains a number of valuations of steam railroad properties brought to a later date than the date of basic valuation, and valuations of pipe line properties; valuations being currently issued will be incorporated in Vol. 48. The first 21 volumes of the valuation reports are not numbered as an independent series but are included in the regular Interstate Commerce Commission report series and bear number from Vol. 75 to Vol. 149, not consecutive. The final valuations vary in size from about 7 pages for short lines which entered no protests to 1,913 pages for the Pennsylvania Railroad system, exclusive of the Panhandle–Vandalia lines, for which a separate report of 450 pages was issued.

Summary of Final Valuations

The so-called basic or primary final valuations of steam railroads, including the electric railroads and steamship companies (such as the Southern Pacific Steamship Lines) operated as parts of steam systems, include the properties of 1,704 corporations having dates of valuation extending from 1914 to 1922 and cost of reproduction estimates based on normal 1914 prices, and 121 corporations coming into existence since 1913 or for other reasons not included in the original program and having 1927 or 1928 dates of valuation and cost of reproduction estimates based on post-war prices.

Of the 1,704 carrier corporations of the original program, 1,044 corporations were operating companies, using carrier property, and 660 corporations owned but did not use carrier property. As of the respective dates of valuation these companies had a total capitalization of $21.3 billions, of which $12.3 billions, or 57 percent, was long term debt, and $9.1 billions, or 43 percent was capital stock. The recorded investment in road and equipment as of the same dates was $19.0 billions, which does not include improvements on leased property, investments in non-carrier property and in affiliated companies, and other investments and assets. The cost of reproduction new of the owned property was found by the Commission to be $16.1 billions, and the cost of reproduction less depreciation $12.8 billions, indicating depreciation of $3.3 billions, a weighted average of 20.5 percent. The commission found the present value of owned lands and rights, as of the date of valuation, to be $2.7 billions and of non-carrier property to be $0.5 billions. The final values found, including $0.4 billions for working capital including material and supplies, were: Owned and used, $13.3 billions; used but not owned, $3.7 billions, owned but not used, $3.4 billions; total owned, $16.7 billions; total used, $16.9 billions.

A summary of the totals for the United States for the steam railroads in the two groups taken from a summary prepared by the bureau of valuation dated November 1, 1934 and corresponding figures for The Pullman Company taken from the final valuation of that company's property, 36 Val. Rep. 845, are given in Table 2.

Final (Single-Sum) Values

A number of the tentative valuations first issued contained no findings of value, nor were such findings made in the first three final valuations issued, those of the *Texas Midland Railroad*, the *Winston–Salem Southbound Railway* and the *Kansas City Southern Railway*, in 1918 and 1919, the orders in these final valuations concluding with the statement: "This order will be supplemented by such further findings and order with respect to the value of the carrier property as may be deemed appropriate." The next final valuation to be issued was that of the *Evansville & Indianapolis Railroad*, decided July 11, 1922; this contained a finding of single-sum value "as that term is used in the interstate commerce act," with no reference to rate-making value, and is the only valuation in which value is so qualified. In subsequently issued tentative and final valuations the findings of value are designated as the values for rate-making purposes.

The commission's conclusions on value, as revealed in various final valuation reports, were that while the valuation act did not specifically require a finding of single-sum value it authorized such a finding; that valuations for capitalization, consolidation, taxation, and rate-making purposes and estimates of exchange value cannot all be made upon the same basis and that it would report the value for rate-making purposes; and that the existence of depreciation in the physical properties could not be disregarded. The commission's conclusion to report rate-making values may have been influenced by the passage of the transportation act, 1920, before any findings of single-sum values had been made; this amendment, among other things, directed the commission to so adjust rates that the carriers would earn a fair return on the value of the property used, and provided for the recapture of excess income. In its final valuation on the *Elgin, Joliet & Eastern Railway*, 84 I. C. C. 587, 611, decided June 3, 1924, the commission states that the value for rate-making purposes is:

> a value the act under which we administer the affairs of carriers engaged in interstate commerce authorizes us to determine, and it is the only kind of value which we now deem it necessary to express in a single figure. As occasion arises for us to state single-sum values of the properties of these carriers in proceedings

TABLE 2

SUMMARY OF FINAL VALUATIONS AS OF ASSIGNED DATES OF VALUATION

	Steam Railroads		*Pullman Co.*
Dates of valuation, from—to	1914–1922	1927–1928	1919
Number of carrier corporations:			
Using carrier property	1,044	111	1
Owning but not using carrier property	660	10	-------------
Total	1,704	121	1
Track mileage:			
Owned and used:			
Main tracks	221,503	2,221	-------------
All tracks	304,266	2,767	23
Used but not owned:			
Main tracks	52,652	303	-------------
All tracks	77,348	501	-------------
Owned but not used:			
Main tracks	52,529	242	3
All tracks	75,587	324	8
Capitalization:			
Long term debt	$12,257,698,774	$169,032,038	-------------
Stocks	9,090,055,823	39,341,019	$117,105,960
Investment in road and equipment as recorded including land	$18,954,806,466	$205,961,225	$144,522,062
Original cost, excluding land:			
Owned and used	(a)	$128,434,671	(a)
Used but not owned	(a)	15,339,127	(a)
Owned but not used	(a)	11,430,340	(a)
Cost of reproduction new, excluding land:			
Pricing period	1910–1914	(b)1923–1928	1910–1914
Owned and used	$13,017,747,516	$134,107,471	$156,254,342
Used but not owned	3,281,220,190	19,829,237	14,012
Owned but not used	3,094,887,280	14,210,095	155,323
Cost of reproduction less depreciation, excluding land:			
Owned and used	$10,310,784,782	$107,856,975	$104,553,115
Used but not owned	2,643,751,244	15,797,057	11,151
Owned but not used	2,500,301,943	11,696,239	104,667
Value of lands and rights:			
Owned and used	$ 1,948,490,005	$ 34,956,425	$ 3,191,989
Used but not owned	890,963,024	7,779,180	33,434
Owned but not used	785,099,637	1,319,272	132,354
Non-carrier lands, rights and structures	$ 535,999,887	$ 8,812,602	$ 104,910
Final value of carrier property:			
Excluding working capital:			
Owned and used	$12,836,375,694	$137,867,754	$113,750,000
Used but not owned	3,657,261,894	23,001,037	44,710
Owned but not used	3,408,816,126	12,976,618	237,786
Total owned	$16,245,191,820	$150,844,372	$113,987,786
Total used	16,493,637,588	160,868,791	113,794,710
Working capital	$ 431,919,400	$ 1,651,805	$ 6,000,000

Note (a)=Original cost not reported.

Note (b)=92 carriers, 1923–1927 period; 25 carriers, 1923–1928 period; 4 carriers, December 31, 1927 (date of valuation).

> other than those involving the fixing of rates or the ascertainment of excess earnings, we shall do so, having recourse for that purpose to data contained in the record and our report and order in this proceeding and in proceedings supplementary hereto. The data necessary to bring the valuation of these properties up to date for any purpose are not now before us, and can be made available only by further inquiry into changes in the property and conditions affecting their value that have occurred since the date of valuation taken for present purposes. We do not now decide as to methods or considerations which shall control our determination of the values for purposes other than rate making, or which will be best adapted to bringing our valuations up to date.

In 1923 the National Conference on Valuation of American Railroads, described as a voluntary organization composed of public officials, representatives of private organizations, and individuals interested in the valuation of railroads and of which Senator Robert M. La Follette was chairman, filed a petition of intervention with the commission, which was supported by a supplemental petition filed on behalf of the Governor of Wisconsin, alleging in part that the valuations as reported by the commission failed to comply with the requirements of the valuation act in that the original cost of railroad property and the amount of public donations to railroads were not ascertained and the methods whereby final valuations were fixed were not reported, and praying that all proceedings then pending be recommitted to the bureau with directions that it ascertain and report such original costs and the amount and value of government aids. The petition as to these prayers was denied (84 I. C. C. 9, decided in 1923), the commission holding that its valuations were in substantial compliance with the statutes, and that a detailed analysis of the method of arriving at the judgment figures for final value would call for a description of mental processes.

The form in which the finding of value was expressed was substantially the same in all but the first few valuations, a typical illustration being:

> FINAL VALUE.—After careful consideration of all facts herein contained, including appreciation, depreciation, going-concern value, working capital, and all other matters which appear to have a bearing upon the values here reported, the values, for rate-making purposes, of the property of * * * , owned or used, devoted to common-carrier purposes, are found to be as follows:
>
> | | |
> |---|---|
> | Owned and used | $ * * * |
> | Owned but not used, leased to– | |
> | * * * | * * * |
> | Used but not owned, leased from– | |
> | * * * | * * * |
> | Total owned | * * * |
> | Total used | * * * |
>
> The sum of * * * is included in the value above stated as owned and used on account of working capital, including material and supplies. Reference is made to * * * for an explanation of the method employed in determining working capital. No other values or elements of value to which specific sums can now be ascribed are found to exist.

In most instances the single-sum values found were a few percent greater than the sum of cost of reproduction less depreciation, present value of land and rights, and working capital; in the values of several properties constructed after the war-time rise in prices the original costs, being greatly in excess of cost of reproduction, appear to have been given predominant weight.

The protests made by carriers against the commission's tentative findings of final single-sum values covered a wide range, such as insistence that the act required a finding of single-sum value, and that it did not permit such a finding; that the value to be reported should be ascertained by adding cost of reproduction new, present value of land and rights, working capital, a stated sum for appreciation, and a stated sum for the intangible value variously described as cost of development or going-concern value; that the act required a finding of value for all purposes, not one for rate-making purposes alone; some carriers protested the discrepancies between the dates of valuation and the pricing periods used for the engineering property, and between the latter and the dates as of which the present values of land were appraised.

Other Values and Elements of Value

The valuation act requires that in addition to reproduction costs, present value of lands, and original costs, other values and elements of value, if any, be reported, with an analysis of the methods employed and the reason for the differences between any such value and the cost values. The engineering board was not requested by the director to make a study of intangible values properly includible in the valuations, and the engineering, land and accounting reports contain no references to such values.

In the opinion of Director Prouty as expressed in a memorandum upon final value addressed to the commission in 1920, a final value of carrier property for rate-making purposes should include an allowance for appreciation and for what he termed structural going value, the latter having no relation to the going value arising from the *successful* operation of the property, or to the early losses from operation. He defined structural going value thus:

> Before a railroad can be successfully run its operating organization must be built up. This is not accomplished by simply hiring so many people. The relation between these people must be established. A working organization must be developed. The same people, after this organization is perfected, will transact much more business and in a much more satisfactory way than at the beginning.
>
> It is also necessary that the operators of these railroads become familiar with the property. Its weak points and its strong points must be developed. What traffic it can handle to advantage, both through and local, and how that traffic is to be obtained and how handled must be thought out. No organization can economically handle the business of a railroad until that railroad is thoroughly understood.
>
> Finally and perhaps principally, this railroad must establish itself with the public. People must learn that there is such a railroad, must come to know the extent to which it can be used, must have confidence in its ability to transact the business which is committed to it.
>
> This kind of going value inheres, so to speak, in the property itself. This railroad, considered purely as an instrument for the obtaining and the transacting of business, has this added element of value. This property has been put into motion. It has become an instrument of traffic. It has acquired a business and is handling that business. It has developed its organization for that purpose. It has established itself as a railroad in the estimation of the public. This kind of going value attaches to the property itself and is the same whether the exchange value of that property is great or small.

In his memorandum the director indicated that in his opinion the allowance for appreciation and going-concern value should be equal to about five years' depreciation of the road accounts, or on the average from five to ten percent of the cost of reproduction new of the road accounts except land but including general expenditures.

"Were Given Consideration"

In its "findings" of single-sum values the commission customarily stated that appreciation and going-concern value were given consideration and that no other values or elements of value to which specific sums could be ascribed were found to exist, but in no instance was a finding made of a definite amount for intangible value, and the commission did not commit itself to the use of a formula. It is considered probable that such allowance as the commission made for intangible value in the basic valuations is represented by the difference between the single-sum values reported and the sum of estimates of cost of reproduction less depreciation, present value of land and rights and working capital. This difference was not uniform for all carriers, but averaged about 4.35 percent for all railroads in the valuations of which 1914 normal prices were used, or about $700,000,000 on a base of about $16,000,000,000.

The commission did not issue an order requiring carriers to file schedules of their claims for intangibles, as recommended by the engineering board, but the Texas Midland Railroad, and possibly other carriers among those first valued, was requested to file a statement of its claims. The carriers generally made their claims in their protests against the tentative valuations, and the subject of intangibles was one of the major points of controversy at the hearings. Much testimony was offered by the carriers, with no rebuttal by the bureau, and extended argument was held before the commission. It was generally alleged that the valuation act required that specific sums for the intangibles be reported, and in some instances claim was made for the inclusion of the cost of the intangibles in original cost. Claims were made for appreciation of excavation and embankment, no allowance for which was made by the bureau in cost of reproduction, and for seasoning of track, as the bureau's prices for track laying and surfacing were for unseasoned track structures.

In its final valuations the commission repeatedly held that it was not required to, and could not, ascribe specific sums to such other elements of value, but that appreciation to the extent that it was found to exist was given consideration in the determination of single sum value, and that the railroads were valued as going concerns, otherwise scrap values would have been assigned to the physical items. It was also held that value for rate-making purposes could not properly include the costs or values associated with or incurred in connection with the intangible variously claimed as good will; franchises and public contracts; development of the property and early losses in operation; strategic location; earning power; market value of securities; training personnel; efficiency of operating personnel; securing the business, value of attached business; sources, nature and density of traffic; contract relations with connecting carriers; capitalized rentals as value of trackage rights; stationery, tariffs, office forms and records, systems of tariffs and tickets; patents; development of sleeping car law; acquisition of right to do business in various states; and promotion of the enterprise.

Cost of the Federal Valuation of Railroads

From the beginning of the valuation work in 1913 to June 3, 1937, the commission has expended about $50,000,000 on this work, and the cost to the Class I railroads has been about $154,000,000, a total of about $204,000,000, or an average of about $830 per mile of road. The cost of the field work, which was substantially completed in

1921, was about $22,000,000 to the commission and about $54,000,000 to the railroads, a total of about $76,000,000, or an average of about $310 per mile of road.

The costs subsequent to 1921 include, in addition to the cost of completing the field work and of preparing the remaining reports, the expense of the hearings of valuation cases, of the recapture work which terminated in 1933, of bringing the valuations down to date, and on the part of the commission, the cost of the valuation of pipe line carriers begun in 1935. The charges to valuation expenses by the railroads

TABLE 3

COST OF THE FEDERAL VALUATION OF RAILROADS

Year Ended June 30	*Cost to Interstate Commerce Commission (a)*	*Cost to Class I Railroads (b)*
1913	$ 10,366	
1914	456,565	$ 1,865,741
1915	2,131,925	2,713,763
1916	2,984,333	5,030,760
1917	3,283,884	7,048,922
1918	3,471,556	8,014.142
1919	3,686,793	8,252,783
1920	3,196,407	9,713,923
1921	2,898,914	11,480,923
1913–1921	$22,120,743	$54,120,957
1922	1,704,591	8,657,862
1923	1,395,737	7,603,164
1924	1,335,751	6,647,487
1925	1,064,655	6,898,925
1926	1,593,830	7,826,763
1927	1,712,052	8,432,409
1928	2,067,141	8,998,772
1929	2,332,013	8,866,879
1930	2,534,979	10,643,504
1931	3,246,694	9,153,940
1932	3,199,491	6,202,034
1933	2,363,163	3,477,499
1934	1,021,904	2,386,484
1935	1,129,819	1,693,349
1936	1,036,921	
1937	797,577	(c) 1,674,207
1922–1937	$28,536,318	(d) $ 99,163,278
1913–1937	$50,657,061	(d) $153,284,235

Note (a)=Includes "added compensation" paid Bureau of Valuation employees, 1918–1924, totaling $959,281.
Note (b)=A few small carriers not included.
Note (c)=July 1, 1935 to December 31, 1936.
Note (d)=To December 31, 1936.

include many costs which would have been incurred in the ordinary course of reporting and recording property changes had there been no valuations made.

Table 3 shows the costs of the valuation work by fiscal years from 1913 to 1937 as reported by the commission in its annual reports and as reported by the Class I railroads (a few small carriers not included) to the Presidents' Conference Committee.

The cost of the valuation and the time required to make it greatly exceeded the estimates of cost and time made when the valuation act was under consideration. In testimony before the House Committee on Interstate and Foreign Commerce in February, 1912, reported in Senate Report No. 1290, 62d Congress, 3d Session, one commissioner quoted (p. 204) Prof. Adams' estimate of cost as being $3,000,000, and expressed the opinion (p. 206) that the work "would certainly take three years or more"; and another commissioner stated (p. 231): "If every cent of expense had to be borne by the government it might run up as high as $5,000,000, assuming the present mileage. As a practical matter * * * I do not believe it would approximate more than one-half of that * * * " and that a complete report could be hoped for "possibly within two and a half to three or four years."

Carriers Other Than Steam Railroads

Sleeping Car Companies

The common carrier property of The Pullman Company, but not its manufacturing plants, was inventoried as of June 30, 1919 and a final valuation thereof issued by the commission; in subsequent reports this valuation was brought down to the date December 31, 1931. No other sleeping car companies are reporting carriers to the commission.

Electric Railways

Street, suburban and interurban electric railways not operated as parts of general steam railroad systems of transportation are exempt from valuation under the act as amended in 1933, unless the commission considers it desirable in the public interest to make a valuation of any such property. In the course of the valuation work valuations were made of a few electric railroads in the same manner as was followed in the case of steam railroads.

Telegraph and Telephone Companies

The telegraph and telephone companies which were common carriers were subject to valuation, and the bureau proceeded with the inventory of such properties concurrently with the valuation of steam railroads and in the same general manner. Three companies owned or controlled most of the physical property to be inventoried, the Western Union Telegraph Company, the Postal Telegraph–Cable Company, and The American Telephone and Telegraph Company. A joint committee representing these companies was formed and met in conference with the director and the engineering board beginning in September, 1913, to formulate plans for these valuations.

Much of the property of the Western Union company is used in whole or in part in railroad communication service; this property was inventoried by the field parties of the bureau in connection with the inventory of railroad property, the telegraph property used in commercial service which paralleled the railroad lines and commercial loops leading therefrom being inventoried at the same time. A tentative valuation of the property, which consisted of about 150,000 miles of pole-line route mileage, was served in 1928, the date of valuation being June 30, 1919 with prices (except land) as of

June 30, 1914. Hearings were begun; joint conferences were not held. Upon application by the company the hearing was recessed, and eventually a new valuation was prepared by the bureau with the co-operation of the company, the date of valuation being December 31, 1931 with prices as of the period from 1927 to 1931. This work was completed by the bureau at the request of the Federal Communications Commission after the transfer to it, in 1934, of jurisdiction over facilities for the transmission of intelligence, and a tentative valuation, without final values, prepared.

A tentative valuation of the property of the Postal Company, having a pole-line route mileage of about 30,000 miles, was prepared by the bureau and served on the company in 1928, the date of valuation being June 30, 1919 and prices (except land) as of June 30, 1914. Engineering conferences were held but the case did not advance to hearings prior to the assumption of jurisdiction over this company by the Federal Communications Commission in 1934, and no final value report on this property was issued by the Interstate Commerce Commission.

Little progress was made on the valuation of the property of The American Telephone and Telegraph Company and this valuation was not completed. Final valuations were issued on only seven telegraph and telephone companies, all of small size with an aggregate final value of less than $250,000.

Pipe Line Companies

Valuation of the properties of pipe line carriers was begun in 1935 and is in progress. The methods and procedure developed in the work on steam railroads are followed. These valuations are being made as of December 31, 1934.

Carriers by Water

Valuations of a few small steamship companies were made in connection with the steam railroad valuations. Lack of funds has been cited by the commission as the reason for deferring valuation work on carriers other than steam railroads.

Express Companies

No valuation work was done on the properties of express companies.

Motor Carriers

The jurisdiction of the commission was extended to cover highway motor carriers by the motor carrier act of 1935, but the commission is not authorized or required by law to make valuations of the property of such carriers.

Bringing Valuations Down to Date

The mandatory provisions of the valuation act of 1913 relative to revisions of valuations were omitted by the amendment of 1933 and the act now requires that the commission keep itself informed of property changes on carriers and their costs, and that it "may keep itself informed of current changes in costs and values of railroad properties * * * and, when deemed necessary, may revise, correct, and supplement any of its inventories and valuations." The 1933 amendment also relieved the commission of the requirement that it keep itself informed of property changes and values "in like manner" as employed in making the original valuations, a change which had been repeatedly recommended by the commission in its annual reports beginning with that for the year 1923 on the grounds that the cost and time required made it impracticable to make revisions "in like manner."

Carriers are required to maintain detailed records showing the nature, extent and cost of all changes in their properties and to report to the commission summaries of such changes, including their costs, as have been made subsequent to the basic valuation dates. These records and reports are provisions of Valuation Order 3, the first issue of which, with regulations and forms, was drawn up by the engineering board and made effective by the commission as of July 1, 1914. The second revised issue of the order, currently in effect, was made effective as of January 1, 1919, since which date one amendment, eight supplements and three revised supplements to the order have been issued. The returns made by carriers to this order are "policed" both as to units and costs at the offices of the carriers by a field staff of accountants and engineers for which headquarters are maintained in eight cities in different parts of the country.

Costs and price trends since 1914 applicable to railroad construction have been collected and studied by the bureau, much of this work being done by joint committees consisting of representatives of the bureau and of the carriers. From time to time the bureau has released summaries of its studies of cost changes made up in the form of railroad construction indices showing, by years, for eight territorial groups and for the entire United States, weighted period index numbers for each account of the steam railroad classification, with costs as of the 1910-1914 period as the base.

The Long Method

For bringing its valuations down to a later date the bureau has developed two procedures, the long method and the short method, so-called, and often uses a combination of the two. When the data and time are available the long method is used, cost of reproduction new being determined by correcting the quantities of the basic engineering reports by the addition and subtraction of the quantities reported added and retired in carriers' returns to Valuation Order 3, pricing the revised quantities at the 1914 normal prices of the basic reports, and multiplying the new totals by index numbers considered appropriate. The overhead accounts, engineering, general expenditures and interest, are computed as percentages of the revised totals.

Cost of reproduction less depreciation is estimated by extending to the new date, on a straight-line basis, the depreciation shown in the basic engineering reports, using engineering board Memorandum 226 as a guide and taking into account renewals charged to maintenance accounts.

The present values of land and rights are determined under the long method by revising the zone areas and classifications of the basic land reports in accordance with the reported changes and pricing the revised areas at units of value as of the new date estimated by the field appraisal organization of the land section.

Original cost, except land and rights, as of the new date is determined by adding the net cost of property changes subsequent to the date of basic valuation to the original cost as of the earlier date when a finding of such cost was made; in most instances such findings were not made, and the bureau then uses as an estimate of the original cost as of the date of basic valuation, the cost of reproduction new at 1914 normal prices, in accordance with the conclusion of the commission, stated in numerous valuation reports, that such reproduction costs are a fair average of the costs of constructing railroads in most parts of the country in previous years. The commission has stated that as of January 1, 1937 approximately 70 percent of the original cost has been recorded and checked, leaving 30 percent, representing construction or acquisition prior to the requirement of original cost records, for which estimates are required. Depreciated original cost, when reported, is taken in the same proportion to original cost that cost of reproduction less depreciation bears to cost of reproduction new.

Working capital including material and supplies is estimated by one of the methods developed in the basic valuation work, the selection of method being based on the data available.

The Short Method

When the requisite time or data for application of the long method is not available the short method is used in the determination of cost of reproduction new and of the present value of land and rights as of the new date. In applying this method the costs of engineering property added and retired in the years subsequent to the date of basic valuation are trended to the 1914 level of prices by the use of divisors, the resulting net cost of property changes at 1914 normal prices added to the cost of reproduction new of the basic valuation and the new totals multiplied by index numbers to bring the estimates to the price level of the new valuation date. Similarly, the charges and credits to Account 2—Land, are adjusted to the new date and added to the present value as of the new date of the land and rights of the basic valuation. The long and short methods are described in detail in an exhibit prepared by the bureau and received in evidence in *Fifteen Percent Case, 1937-1938,* Ex Parte No. 123.

The commission has made findings of final value for rate-making purposes as of recent dates, based on the elements of value reported by the bureau, of the properties of a number of railroads in connection with consolidation, reorganization and other proceedings, final valuation reports being issued similar to those prepared during the basic valuation work; in some instances tentative valuations were served, protests received and hearings held. The commission has also made findings of the value as of recent dates of all the carrier property in territorial groups and in the United States in connection with various rate proceedings without determining the values of the individual properties, these findings being based on the aggregates of the elements of value as computed by the bureau for the individual carriers. The values found for individual railroads and pipe line companies and for railway carrier property in territorial groups as of recent dates are approximately the same as the sum of original cost and cost of reproduction weighted and depreciated, present value of land and rights, and working capital, plus an allowance of usually about two to four percent of that sum.

Recapture of Excess Income

The provisions of Section 15a of the interstate commerce act, added by the transportation act of 1920, greatly increased the work of the Bureau of Valuation. This section established a new rule of rate-making and provided for the recapture by the government of one-half the amount by which the net railway operating income of a railroad in any year exceeded six percent of the value of its property. These provisions were repealed retroactively by the emergency railroad transportation act of 1933 before judicial interpretation had been rendered of many of the important and interesting questions involved. Section 15a provided that rates should be so adjusted as to yield to the carriers as a whole under "honest, efficient and economical management" a fair return upon the aggregate value of the property used in transportation service, and set such fair return at 5½ percent for a period of two years from March 1, 1920, but allowed the commission the discretion of adding an additional amount not exceeding one-half of one percent to make provision for improvements, betterments or equipment chargeable to capital account. In consideration of the condition of the carriers at the termination of federal control the commission, in *Increased Rates, 1920*, 58 I. C. C. 220, set the fair return at the maximum allowable figure of 6 percent and approved substantial increases in rates; subsequently, in *Reduced Rates, 1922*, 68 I. C. C. 676, 734, the commission established 5¾ percent, after adjustment for federal income taxes, as a fair return effective March 1, 1922, which it estimated as approximately the equivalent of a return of 6 percent before deduction of income tax. No further change was made in the established rate of fair return.

Applied to Individual Carriers

The provision for the recapture of excess income applied, however, to individual carriers, the theory being that with rates so set as to yield a fair return on the average, the more fortunately situated roads would receive a greater than average return, a part of which would be payable to a fund administered by the commission for the benefit of the less fortunately situated carriers. The amendment provided that earnings in any year in excess of six percent of the value of the property used in transportation service should be considered as excess earnings, one-half of which should be retained by the carrier in a special reserve fund, and one-half paid to the commission for the purpose of establishing and maintaining a general railroad contingent fund.

A carrier having such a reserve fund was permitted by the statute to make withdrawals therefrom to the extent that its net railway operating income in any year was less than six percent of the value of its transportation property, but only for the purpose of paying dividends, interest or rent for leased roads until such time as the reserve fund had reached five percent of the value of the carrier's property, when the carrier's portion of additional excess earnings was usable for any lawful purpose.

The general railroad contingent fund was to be a revolving fund from which loans were to be made to carriers to meet expenditures for capital account, or to refund maturing securities originally issued for capital account, or for the purchase of transportation equipment and facilities to be leased to carriers. The rate of interest on the loans from the fund was set by the statute at six percent, adequate security was required, and rental from leased equipment or facilities was required to be at least sufficient for a return of six percent upon its value in addition to depreciation. The conditions thus prescribed in the amendment were less attractive than could be obtained in the open market by carriers able to furnish the required security.

Newly constructed lines were exempt from recapture for a period of ten years under certain prescribed conditions, and consolidated returns were permitted in the computation of recapture obligations by corporations whose lines were operated as a system.

The Work Involved

In administering the provisions of Section 15a the commission was obliged to examine the accounts of carriers thought to be subject to recapture and determine their net railway operating income, and also to determine the value of the property used in transportation service as of the recapture years. These accounting activities comprised the principal activities of the field force of the Bureau of Accounts from 1923, when recapture work was begun, to 1933, when the provisions were repealed, and more than 4,000 of such income investigations were made. In the course of the recapture work the Bureau of Valuation submitted valuation chapters for more than 200 recapture reports, each chapter containing the necessary data for the ascertainment of fair value for each year beginning with 1920 it was estimated that excess income had been earned by a carrier. Prior to 1930 recapture proceedings were handled as "proposed report" cases without service of tentative reports prior to the hearings, the examiners before whom the hearings were held submitting proposed reports to which the parties were permitted to file exceptions. Beginning in 1930 the procedure was changed to conform to that of the valuation cases and tentative recapture reports against which protests were made were served on the parties in advance of the hearings.

All carriers were required by order of the commission to file annual statements reporting, under oath, net railway operating income, value of the property as estimated by the carrier, and the amount of excess income, if any. From these reports the commission selected for examination those roads which had earnings approaching or in excess of six percent of their value as estimated by the commission's staff.

The "O'Fallon" Case

Much litigation resulted from the recapture legislation. The constitutionality of these provisions was upheld by the Supreme Court of the United States in *Dayton–Goose Creek Ry. Co.* v. *United States et al,* 263 U. S. 456, decided in 1924. The leading case in the matter of the principles of valuation applicable in computations of excess earnings was that of the St. Louis & O'Fallon Railway Company, for which the commission entered an excess income report and order in February, 1927. This report, 124 I. C. C. 3, 42, states:

> The method which we therefore find logical and proper for determining the value in the subsequent recapture periods is to add to or subtract from the 1919 value the net increases or decreases in the investment in property devoted to transportation service as determined from the carrier's returns to valuation order No. 3, with due regard to the element of depreciation.

The "1919 value" referred to was the final valuation under Section 19a as of June 30, 1919 based on cost of reproduction estimated at 1914 normal prices plus the amount by which the actual cost of property other than land added between July 1, 1914, and June 30, 1919, exceeded the reproduction costs of such property at 1914 normal prices.

Four commissioners dissented from this decision, pointing out that the method of valuation adopted was not in accordance with principles bearing court approval and stating, at page 59: * * * we venture the reminder that the function of this commission is not to act as an arbiter in economics, but as an agency of Congress, to apply the law of the land to facts developed of record in matters committed by Congress to our jurisdiction.

The O'Fallon petitioned the district court to enjoin and annul the commission's order, on several grounds of which the method of determining value was one. In commenting on this proceeding in its 1927 annual report the commission said: "If approved by the courts, it is thought by the majority that the method of valuation adopted in this case will be practicable and workable in the administration of the recapture provisions and will produce results just and fair to carriers and the public."

The district court did not pass on the question of the method of valuation and the case went up on appeal. In its decision, 279 U. S. 461, May 20, 1929, the Supreme Court of the United States held that the commission should have given consideration to reproduction costs as of the date of the finding of value, saying in part that Section 15a "directs that in determining values * * * the commission 'shall give due consideration to all the elements of value recognized by the law of the land * * * .' This is an express command * * * . 'The elements of value recognized by the law of the land * * * ' have been pointed out many times by this court * * * . Among them is the present cost of construction or reproduction."

Following the decision in the O'Fallon case the values used by the commission in the determination of excess income appear to be based on original cost and cost of reproduction as of the beginning of the year, weighted and depreciated, plus the present value of land and rights, working capital and the net cost of additions, betterments and retirements for the year under consideration weighted to reflect the time in service during that year and depreciated.

Repeal Recommended

In 1930 the commission began its repeated recommendations to Congress that the recapture clauses of Section 15a be repealed, pointing out the difficulties and cost of administration, the litigation that was in prospect, the lack of use for the contingent fund under the circumstances, and other defects in the law as it stood.

The commission estimated that about 448 railroads earned excess income in one or more years in the period from 1920 to 1931, with a total recapture liability of about $360,000,000. The total recapture liability admitted by the carriers in their annual returns to the recapture orders was about $12,000,000, of which about $10,000,000 was paid into the contingent fund, most of such payments being made under protest and with reservations. The fund earned about $3,000,000 in interest, which was refunded to the contributing carriers, with the principal sums, on the basis of the amounts of their respective contributions and the length of time the funds were in the government's custody, after the recapture provisions had been repealed in 1933.

Uses of Valuations

As the valuation work progressed it became clear that the widely held, and politically fostered, view that the railroads were greatly overcapitalized was incorrect as to the carriers as a whole, although a number of individual carriers, both great and small, were found to have capital structures in excess of the value of their assets. In his report on regulation of railroads transmitted by the commission to the President of the Senate on January 20, 1934, the federal co-ordinator of transportation said:

> Contrary to much popular impression, the railroads are not in the aggregate overcapitalized, in the sense that the par value of outstanding securities exceeds the money invested in the properties. * * * While there was much inflation of the original capitalization of many railroads, this has since been offset, in the aggregate, by two principal factors: (1) Much investment of surplus earnings in carrier property by the more prosperous railroads, and (2) the scaling down of original capitalizations through reorganization.

The first instance in which the commission made a general finding of value based on the valuation records for use in rate proceedings was in *Increased Rates, 1920*, Ex Parte 74, 58 I. C. C. 220, decided July 29, 1920. At that time the primary valuation work of the bureau was far from completed and little, if any, work had been done toward bringing its estimates down to date, but using such information as was then available, supplemented by statistics from other sources, the commission made the finding that "for the purposes of this particular case" the value of the steam-railway property of carriers subject to the act was approximately $18,900,000,000 and made a division of that amount among the three rate groups considered in that case.

In *Reduced Rates, 1922*, Docket 13293, 68 I. C. C. 676, decided May 16, 1922, the commission made no finding of value but indicated in its decision that the finding made in Ex Parte 74 adjusted for the costs of subsequent property changes and for additional depreciation governed its decision in the matter of rates.

In *Fifteen Percent Case, 1931*, Ex Parte No. 103, 178 I. C. C. 539, decided October 16, 1931, the commission again made no finding of value but indicated that estimated return was computed on a value found by adding net additions and betterments to the value found in Ex Parte 74; based on the amounts and rates of return as estimated by the commission the value used as a base was about $24,500,000,000.

In *General Rate Level Investigation, 1933*, Docket No. 26000, 195 I. C. C. 5, decided July 31, 1933, the commission again made no finding of value but there were received in evidence in the proceedings estimates by the bureau of the elements of value for the Eastern, Southern and Western districts and for the country as a whole. In these estimates cost of reproduction included the property as of December 31, 1932, at both "period" and "spot" prices as of June 1, 1933, present value of land included the property as of December 31, 1932, at values as of June 1, 1933, and original cost except land, and working capital, were as of December 31, 1932.

In *Southwestern–Official Divisions*, Dockets Nos. 25390 and 25692, 216 I. C. C. 687, decided March 9, 1936, there were received in evidence in the proceedings estimates by the bureau of the elements of value as of December 31, 1933, for the railroads in Eastern territory with and without the Pocahontas lines, and for those in Southwestern territory with and without certain carriers included. No findings of value were made but the commission estimated rates of return on three bases; Base A being cost of reproduction less depreciation plus value of lands and rights plus working capital; Base B, original cost plus value of lands and rights plus working capital; and Base C, cost of reproduction and original cost weighted and depreciated plus value of lands and rights plus working capital.

In *Fifteen Percent Case, 1937–1938*, Ex Parte No. 123, 226 I. C. C. 41, decided March 8, 1938, the commission made findings of value, and the bureau prepared estimates of the elements of value at period prices which were received in evidence, as of January 1, 1937, separately for Class I, Class II, Class III and switching and terminal companies for each of the eight regions customarily used by the commission in its statistical reports. In one of the exhibits in this proceeding prepared by the bureau the elements of value of all individual Class I carriers are given.

Introduced in Other Cases

The bureau's estimates have been introduced in other rate cases of less general interest, and the commission has found the valuation records of great usefulness in many other proceedings, notably in those for the recapture of excess income, in passing upon applications for the issuance of securities under Section 20a (2) of the interstate commerce act, in bankruptcy reorganization proceedings of a number of railroads under Section 77 (e) of the bankruptcy act as amended, 1935, in authorizing annual rates of depreciation to be charged by carriers and in proceedings relative to handling charges at Great Lakes docks.

With the passage of time many concomitant uses of the commission's valuation records and the personnel of the bureau, not originally contemplated, have developed. State, county and municipal governments have made use of the records in connection with freight rate, taxation and other matters, conservation districts in connection with flood control programs involving the inundation or relocation of railroad properties, the carriers themselves in connection with many matters including refinancing applications before the Securities and Exchange Commission, and private individuals have been given access, within limits, to the records of the bureau.

Among the federal departments which have been served have been the Department of Agriculture and its Bureau of Public Roads; the Department of Commerce; the

Department of the Interior and its Geological Survey; the Department of Justice; the Department of Labor; the Post Office Department; the Treasury Department, and its Bureau of Internal Revenue which often refers to the bureau's records in connection with taxation matters; and the War Department.

Many of the independent agencies of the federal government have had occasion to make use of the valuation records. These include the Federal Communications Commission; the Federal Co-ordinator of Transportation, who was furnished valuation data for use in connection with his study of the advantages of consolidation of railroads and in connection with the co-ordination of facilities in the Chicago terminal area, and to whom personnel was loaned; the Federal Emergency Administration; the Federal Power Commission; the Federal Trade Commission; the Home Owners' Loan Corporation; the Public Works Administration; the Reconstruction Finance Corporation; the Tennessee Valley Authority; and the Works Progress Administration.

Conclusion

The author has devoted his time almost exclusively for 25 years to valuation work and a study of the valuation question and it is his opinion that while the cost of making the valuation of railroads was comparatively high, the task could not have been performed in the detail required by the valuation act at less expense. It was necessary to train a large corps of engineers, land appraisers and accountants, and to prepare complete inventories with lists of items of property, all of which required much time, effort and expense. The work has been done in such detail and so thoroughly that the inventories of railroad property can be kept up to date by adjustments for the quantities added and retired which are reported by the railroad companies in detail annually to the commission.

It is the conclusion of the author that the valuation reports are valuable and will prove to be of great service in the future to the railroad companies, the public and the government.

Acknowledgment

This paper was prepared in 1938 from original records. The author acknowledges the co-operation of his associate, L. T. Fleming, who made an exhaustive investigation of original records and official documents relating to valuation and collected and assembled the data.

Railway Car-Ferries, American and Foreign*

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INTRODUCTORY.—Important railway routes on both main and secondary lines are often intercepted by streams, rivers, arms of the sea, or other bodies of water for which bridges are impracticable or of prohibitory cost. A very general expedient in dealing with such cases or problems in a practicable and economic manner is to establish a car-ferry—more often known abroad as a train-ferry—for the transfer of cars and trains, in order to avoid the disadvantages of transferring passengers and freight from car to boat and again from boat to car. Such transfers involve much delay and inconvenience especially in bad weather, and also an inevitable increase in loss and damage to freight due to the rehandling. It may be that even railroad men, shippers and transportation and commerce men in general, when not directly concerned with car-ferries, do not realize the extent of car-ferry service or its importance as a feature in the railroad transportation system. An indication of this importance is the fact that the Pere Marquette Railway is now (1940) having a new car-ferry steamer built as an addition to its fleet on Lake Michigan. This new vessel, the largest and most powerful of its type on the Great Lakes, is to be completed by 1941.

Railway car-ferries are in operation in numerous parts of the United States, and also in many foreign countries. The American railway system has not only by far the largest number, but is noted for the operation of several lines on Lake Michigan, which makes the service of particular interest and importance. Descriptive articles on American car-ferries, as prepared by the writer, were published in "The Engineer", of London, England, in March–April, 1906, and April, 1932. The present report has been prepared with the special purpose of putting on record some information as to the development and equipment of these rail-and-water services as important links in railway transportation systems. There is no attempt to include each and every car-ferry line, but the intent is to show something of the history, development and utilization of this special method of railway transportation, together with the various conditions encountered in their operation. As to the notes on car-ferries in Europe, it is to be borne in mind that the present war has disorganized all transportation services, and the information given refers to normal conditions before the outbreak of the war in 1939.

There are practically three classes of car-ferry service: (1) Lake and ocean transfer by large sea-going vessels; either in sheltered inlets and bays, or in open sea and subject to storms and rough weather; (2) river transfer by steamers, motor vessels and barges, and (3) harbor transfer, mainly by barges or car-floats handled by tugboats. For lines of the first class, vessels with high freeboard and enclosed car deck are required in order to be seaworthy. For the other two classes, low freeboard and open deck are sufficient. The routes range from 2 miles to 100 miles. But there is also a rather special and very limited class which consists of long-distance "longitudinal" routes rather than the ordinary crosswise routes. For example, there is the American service between Atlantic, Gulf and Cuban ports; and in South America there is a 126-mile route on the River Plate, where a 300-mile line was at one time proposed. In the United States, there was a 240-mile route operated between north and south points on Lake Michigan, but this was abandoned some years ago.

In a majority of cases in this country only freight cars are handled, and these not as complete through trains. Incoming trains at one port are broken up in the terminal yard, and certain through cars are ferried across and placed in the opposite terminal yard on the opposite side, ready to be assembled into outgoing trains. Passenger cars and trains are handled only in exceptional cases. Very rarely are the locomotives transferred by ferry, and then generally where the ferry is distant from division points and the train has to be handled as a complete unit. The average time of handling the cars is 1.15 minutes for unloading one car from the boat, and 1.32 minutes for loading one car on the boat. These figures are given in a report of the American Railway Engineering Association (Yards and Terminals committee, 1935), and are based on returns from 15 car-ferries.

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* This is a revision and amplification of a monograph published in Bulletin 387, July, 1936. See bottom of page 179 of this volume.

Bridges, Tunnels and Car-Ferries

The notable increase in the construction of long bridges and long bridge spans under difficult conditions, in recent years, has resulted in the abandonment of several car-ferry lines in this country and abroad. Tunnels have had a similar effect, but to a much more limited extent. Examples of such bridge developments are the Mississippi River bridges at New Orleans, Thebes, Cairo, and other points; the Suisun Bay bridge of the Southern Pacific Company in California; the present and proposed bridges in Denmark, and the long bridge over the Zambesi River above Chindio, in Portuguese East Africa. There is also a project for a long bridge with suspension spans to cross the Straits of Mackinac, in Michigan, and supersede both a railway car-ferry and an automobile ferry. Of tunnels which replace car-ferries, there are the St. Clair River and Detroit River tunnels in the United States; and the tunnel recently completed under the Shimonoseki Strait, in Japan, connecting the government railways on the main island with those on the smaller island of Kyushiu.

Historical Notes

The car-ferry idea is no modern development, but dates back nearly a hundred years. In fact, it was, and is, an obvious solution of the problem of carrying a railway across an intersecting waterway, the bridging of which is impracticable or of prohibitive cost, at least until conditions of finance and traffic are more favorable. Apparently the first railway car-ferry was in Scotland, in 1849, when the "Leviathan", of 417 tons, was put in service by the (then) Edinburgh, Perth & Dundee Railway to carry its trains across the Firth of Forth between Granton and Burntisland. The steamer was 167 ft. long, 34.6 ft. beam and 8.6 ft. deep, having an open deck with track capacity for 34 of the small four-wheel freight cars then, as now, typical of British railway equipment. It seems that passenger cars were not carried, the passengers presumably crossing on an ordinary steamer.

The Leviathan was a side-wheel steamer, with an engine of 210 hp. having two cylinders 56 by 42 in. There was probably ample boiler capacity, as the boat had four funnels. Connection between the tracks on land and those on the car deck was provided by a cradle which was moved up and down an incline track in accordance with changes in water level. This boat was sold in 1890 and was broken up in 1892, after the opening of the Forth bridge.

About 1849 or 1850, a similar car-ferry steamer for the (then) Edinburgh & Northern Railway was built to carry trains across the River Tay, at Broughton Ferry, near its mouth, where the width is about 1½ miles. This boat was 180 ft. long and 35 ft. beam, with three tracks and an engine of 250 hp. It appears to have handled passenger cars or trains. As the land on either side is considerably above the water level, stationary engines with cables are reported as being installed to move trains on inclines to and from the ferry landings. Both of these early boats were in service for many years, but were superseded eventually by bridges.

In 1857 a car-ferry was proposed for crossing the River Tees, in England, but the project did not come to fruition. In 1862, a model of a train-ferry designed by Evan Leigh was shown at the International Exhibition, in London, and a project based on this patented system was proposed for the channel crossing, between England and France. In 1865, a car-ferry steamer for the Prussian State Railways, to operate on the Rhine pending the construction of a bridge, was built in England by the Wigham Richardson Co. And in 1872, the same firm built the "Lillebelt", the first of a fleet of car-ferry boats for the Danish State Railways. This boat, of 390 tons and 9-knot speed, was in service until the completion of a bridge over the Little Belt channel in 1935. In 1890 the Tralleborg–Sassnitz car-ferry was put in service between Sweden and Germany.

In the United States, a car-ferry was in service on the Susquehanna river in 1855, and the ferrying of cars between railway terminals in New York Harbor was in operation in 1875 or 1878. These New York ferries consisted of barges or car-floats fitted with tracks and handled by steam tugs. It is likely that some of our western rivers were crossed in this way in the early days of railroads, when lines were spreading rapidly over the country. The Southern Pacific car-ferry carrying main-line trains across the Carquinez strait began operation in 1880, and in 1881 through trains between Boston and Philadelphia were ferried across the Hudson river at Fishkill, N. Y. In 1885, the Pennsylvania Railroad began ferrying cars across Chesapeake bay, from Cape Charles, Va., to Norfolk. The car-ferry across the Straits of Mackinac was started in 1888, and the first of the now numerous car-ferries crossing Lake Michigan began operating in 1892. A "longitudinal" car-ferry line between Peshtigo and Chicago was started in 1890.

Modern developments in car-ferry transportation are described in the following pages. Among the most recent additions is a service across the Danube river between Giurgiu, Roumania, and Rustchuk, Bulgaria, to connect the state railways of the two countries. And curiously enough, projects for a bridge have been refused sanction for many years, for the express military purpose of keeping these countries isolated from each other. The car-ferry was to have been put in operation in December, 1939. Another recent project is for a car-ferry across the Bosphorus, sponsored by the Turkish Government Railways. It is intended to operate between Birkedji, near Istanbul (Constantinople), as a terminal of the railway systems of Europe, and Haidar-Pasha, the western terminal of the Asiastic lines.

Besides the river, lake and ocean car-ferries of the American railways, there are river lines in Canada, India, Africa, South America and even China. There are deep-sea lines between England and Belgium, between England and France, between Denmark and Germany, between Denmark and Sweden, and between Italy and Sicily. In Japan, also, car-ferries connect the railways on the several islands of the empire and with those of Chosen (Korea) on the mainland.

Part I.—Lake Michigan Car-Ferries

The extensive system of car-ferries on Lake Michigan warrants special consideration, since it constitutes by far the largest car-ferry system in the world. Its striking features include: (1) The number of railways and routes served; (2) the number and size of steamers operated; (3) the number of terminal ports; (4) the amount of traffic; (5) the length of voyages between ports; and (6) the modern equipment employed. In addition, the deep-water operation, subject to sudden and violent storms, heavy seas and severe ice conditions, represents an unusual combination of operating difficulties.

Six railroads, independently or jointly, operate nine routes across the lake, serving ten ports and terminals. The service is maintained by a fleet aggregating some 20 large and powerful steamers, built as ice-breakers. These vessels operate all the year round, and in all weathers. Since the lake is approximately 60 to 80 miles wide and 360 miles long, the steamers for these long-distance deep-water lines are of the sea-going type, quite different from those for the crossings of large rivers. Except for a nine-mile route across the straits at the head of the lake, the trips are 65 to 100 miles in length, and occupy from five to eight hours. Passenger trains are carried only on the one short route, but nearly all the steamers carry a limited number of motor vehicles on the train deck. As a rule, the boats do not run according to regular schedules or timetables, but make as many trips as are necessary to handle the business promptly. At periods of heavy traffic, therefore, an incoming boat may discharge its load of cars, take on another load and start at once on another trip. However, for the accommodation of motor vehicles and passengers, some of the lines run a few boats daily at stated times, and such additional boats as may be required.

This service originated in the fact that Lake Michigan intersects several direct rail routes. There are alternative all-rail routes around the south end of the lake, but these involve additional time and expense. From Buffalo, N. Y., to Manitowoc, Wis., the distance is about 700 miles by all rail and 520 miles by the ferry route. The loss of time, as between various points of origination and destination of cars, has been stated as ranging from 12 hours to two days. The delay occurs largely in getting through the congested Chicago gateway, especially with the transfer of cars from one trunk line to another through the intermediary of belt or transfer railroads. This includes detention in two or more freight yards before the car is finally coupled into an outbound train to continue its journey. Although these cumulative delays have been reduced materially through careful management, there is also the terminal charge, which the delivering railroad has to pay for the transfer service. In addition, there is some increased liability of damage to car or freight due to the considerable amount of switching in the interchange and yard handling. Furthermore, for traffic destined to and from a large lake city, such as Milwaukee, the eastern railroads operating car-ferries can handle the cars direct on their own rails (floating) and at their own terminals, instead of routing them through Chicago interchange lines and then over other trunk lines to destination.

In 1928, two of the lines carried about 100,000 cars each in transfer across the lake. The municipal car-ferry terminal in the harbor at Milwaukee, Wis., which is used by only one of the two railways operating car-ferries at that port, handled in 1939 approximately 18,600 cars (loaded and empty), with some 290,000 tons of freight. Its peak business was 26,721 cars in 1930. Including all the car-ferry facilities at Milwaukee, the total car-ferry tonnage in and out of that port in 1935 was 1,494,887 tons.

NAVIGATION CONDITIONS.—These Lake Michigan car-ferries are in operation daily throughout the year, and have to encounter severe conditions owing to violent storms and heavy ice. It is only rarely that a trip is cancelled on account of rough weather. In winter, however, the boats are likely to be delayed occasionally by having to force their way through the ice fields or the masses of ice piled up near the shore by high winds. Severe storms and high seas are not infrequent, but the ice conditions are troublesome owing to their long continuance. The ice is sometimes 3 ft. to 6 ft. thick, and may be piled up as high as 14 ft. by the wind. In deep water, the boats break through, either by means of their inclined stems and wedge-shaped bows, designed as ice-breakers, or by backing into the ice, so that the screws create a swirling movement of the water and a downward current or suction that disturbs and dislodges the ice.

At some of the ports, especially on the east coast, trouble has been caused by ice blocking the entrance to the harbor. A feature of ports on the east or Michigan side of the lake is that they are inland, situated on small lakes formed by rivers which have outlets to Lake Michigan by natural narrow channels cut through the line of high sand hills along the coast. The old type of harbor entrance, built 50 or 60 years ago, to accommodate the small craft of those days, consisted of the natural channels dredged and straightened, widened to about 200 ft. and lined with rock-filled timber cribs, the cribbing being continued to form parallel piers or jetties extending about 1,600 ft. into the lake. The ends of the piers were marked by lighthouses and marker lights. Large ships must approach such a channel practically in an axial direction, which is not always easy in stormy or foggy weather, or when ice fields block the approach to the entrance. When the channel is choked with ice driven in by the wind, even the large car-ferry steamers, which are built as ice-breakers, may have difficulty in getting through to the inland harbor.

In a new type of harbor entrance built at some of these ports by the U. S. Government, in order to improve the navigation facilities for modern large passenger and cargo steamers, the long parallel piers are replaced by breakwaters which are spaced about half a mile apart at the shore line but converge to an entrance opening 400 ft. wide between the heads, thus enclosing a triangular or so-called "arrowhead" bay. This entrance is twice as wide as that of the old plan, and instead of having to negotiate a long and narrow channel, the steamers have a large enclosed and protected bay in which to make their way to the river mouth forming the entrance to the harbor proper.

At Frankfort, Mich., the two new breakwaters extend almost directly from the shore for about 1,600 ft. and then converge for a length of about 1,200 ft. to the heads, which are 400 ft. apart. The first or shore portion consists of two rows of wood piles and sheeting with rock fill. The outer or deep-water portion has hollow concrete caissons sunk in place on a bed of broken stone and then filled with stone and sealed with concrete. The superstructure for the entire length consists of concrete blocks poured in place, while both sides are protected against wave action by riprap of massive quarry blocks, some weighing nearly 20 tons.

Development of Lake Michigan Car-Ferries.—This car-ferry system was initiated in 1888, when the Mackinac Transportation Company put in service a boat across the Straits of Mackinac, at the head of Lake Michigan, to connect the terminals of the Michigan Central Railroad and the Pennsylvania Railroad at Mackinaw City with that of the Duluth, South Shore & Atlantic Railway at St. Ignace, a distance of about 8 to 10 miles. A barge car-ferry up and down the lake, between Chicago and Peshtigo, Wis., was started in 1890, but discontinued a few years later.

For the long or open-sea crossing of the lake, the Ann Arbor Railroad was first, putting two boats in operation in 1892 between its terminus at Frankfort, Mich., and that of the Green Bay & Western Railroad at Kewaunee, Wis. Later, it established additional routes from Frankfort to Menominee and Manitowoc, Wis., and Manistique, Mich. In 1897, the Pere Marquette Railway entered the field. This line ends at Ludington, Mich., some 80 miles south of Frankfort, and its first service was with one boat between Ludington and Manitowoc. The Chicago & West Michigan Railway started a boat between Muskegon, Mich., and Milwaukee in 1898, but this railway was soon acquired by the Pere Marquette, which then changed the route, operating the boat between Ludington and Milwaukee. To these two routes it later added a third, to Kewaunee. In 1906 the Grand Trunk Western Railway—now a part of the Canadian National Railways—started its car-ferry between Grand Haven, Mich., and Milwaukee, Wis., but in 1933 it adopted Muskegon, instead of Grand Haven, as its eastern port.

The Ann Arbor now operates four lines from its terminal at Frankfort, Mich., to Manitowoc, Menominee, Kewaunee and Manistique. The Pere Marquette operates three lines from its terminal at Ludington, Mich., to Milwaukee, Manitowoc and Kewaunee.

The Grand Trunk Western has its line from Muskegon to Milwaukee, and in this ferry (operated by the Grand Trunk–Milwaukee Ferry Company) the Pennsylvania now has a half interest.

Most of the ten car-ferry ports are served directly by two to four railways, although Frankfort and Ludington have but one railway each. As all these railways have numerous connections with other lines, their car-ferries serve as links in various through routings. Each railway has from two to nine steamers, or about twenty in all, and in one recent year the traffic on all routes aggregated 4,400,000 tons of freight and 14,000 passengers.

The distances range from 65 to 100 miles, the longest being from Ludington to Milwaukee and northward from Frankfort to Manistique. The time is from 4½ to 8 hours, according to distance, weather and load, and the engine power. Most of the boats have a sea speed of 14 to 15 miles an hour, but the new turbo-electric steamers, put on in 1930, can make 18 miles an hour. For the short route across the Straits at the head of the lake the time is forty-five to sixty minutes. The several routes and approximate distances are as follows:

	Miles
Muskegon to Milwaukee	85
Ludington to Milwaukee	90
Ludington to Manitowoc	65
Ludington to Kewaunee	65
Frankfort to Menominee	80
Frankfort to Manitowoc	80
Frankfort to Kewaunee	65
Frankfort to Manistique	100
Mackinaw to St. Ignace	9

CAR-FERRY STEAMERS.—Owing to the heavy storms, rough seas, the dangers of a lee shore, the severe ice conditions, and the necessity of maintaining service all the year round, the Lake Michigan car-ferry steamers have to be substantially built and powerfully engined. A high freeboard and a covered or enclosed train deck are essential, as an open deck would be buried under the heavy seas. In this respect the conditions of the lake boats differ widely from those of the numerous car-ferry steamers which operate on river routes and have only light superstructures above the train deck.

In appearance the lake car-ferry steamers resemble lake and ocean cargo boats, except for the stern opening (or bow opening in a few cases, as noted later) to admit the cars. During the voyage the opening is partly closed by a hinged bulwark or sea-gate about 6 ft. high. Up to the main deck, the hull is of very heavy construction, with bulkheads forming water-tight compartments, and with heavy framing and diaphragms to reinforce the ice-breaker bow. Above this deck, the frames and side plating are continued to the upper deck, which forms the roof over the entire train deck, except for a short distance at the stern.

On account of the exceptionally severe ice conditions and the necessity of keeping navigation open in spite of these conditions, the train-ferry steamers are all designed as ice breakers. The special form of bow for this purpose is one of the distinctive features, and is based on long experience. Beginning at about 5 ft. above the train deck level, the stem slopes back in a long curve that meets the keel about 40 ft. from the bow perpendicular. Furthermore, in this 40 ft. distance the sides of the hull slope inward sharply from the main deck level to the stem and keel, thus forming a decided wedge section which is heavily braced on the inside. If the ice is too thick or massive to be sheared and thrust aside by the sharp stem, the forward movement of the boat will tend to cause the fore part to ride up on the ice and thus break it and crush it down by the wedge-shaped bow, and the great weight of the steamer. Slush ice, however, is quite as troublesome as the heavy solid ice.

Beyond this special ice-breaker bow construction, the hull is of the usual approximately rectangular section, with flat floor and heavy keel plate and girder. In heavy cross or quartering seas the steamers roll quite considerably. Bilge keels have been considered as a remedy. But while these would effect an improvement when sailing in open water, they would be a serious handicap when working in slush ice, as this ice would form around the bilge keels and make it difficult to release the ship. The use of the gyro-stabilizer has been considered also, but its expense would be exceptionally high, and so far no such installation has been made.

Long superstructures on the upper deck contain the officer's quarters, deck crew's quarters, galley, mess rooms, public dining room, and other accommodations. There is a large saloon for passengers, with staterooms arranged along each side. A smoking-room, women's room, bath and toilet rooms are also provided. Most of the boats can carry 100 to 200 deck passengers, as when used for day excursions on holidays, and they have sleeping accommodations for 40 to 50 passengers. On some of the later and larger boats, the superstructure is topped with a promenade deck or boat deck extending the full width of the hull. Above the forward break of the promenade deck is the large wheel house or pilot-house, and in some cases the officers' quarters are in a structure at the rear of the pilot-house. In other cases, the pilot-house is above this structure, and is surmounted by the navigating bridge. At the after end of the upper deck is a second large wheel house from which the steamer is handled when backing into its landing slip.

Engine-rooms, boiler-rooms, coal bunkers and allied facilities are all below the car deck. Along the center line of this deck is a narrow enclosure containing the stairways to the upper deck, the companionways to engine and boiler-rooms, and the ventilator shafts and uptakes to the funnels. On the train deck are four lines of rails, each accommodating six to eight cars. These tracks converge into two at the stern. Their forward ends terminate at massive steel bumpers built into the deck framing.

To secure the cars in place and prevent any movement caused by the pitching and rolling of the boat in heavy seas, rail stops or chocks are placed against the wheels and clamped to the rails. These chocks prevent any longitudinal movement. The trucks are also chained down to the rails. Inclined screw jacks are set with their feet resting against jacking rails riveted to the deck plates, while their heads fit against the bottom corner of the car body or the side sill. These jacks are extended so as to take the weight of the car body off the springs and give the body a rigid support, so that it cannot rock or sway on the springs if the boat encounters heavy weather.

For propulsion, all the boats have twin screws, which are controlled independently so as to assist in turning and maneuvering. Most of them have triple expansion engines and Scotch boilers, and all burn coal. However, two boats put in service in 1930 have turbo-electric generators delivering current to motors which are coupled directly to the screw shafts. These two boats also have water-tube boilers with mechanical stokers, coal crushers and chain conveyors. The twin screws are well housed under the stern.

Triple-Screw Steamers.—In some of the earlier boats, a third screw was arranged at the bow to assist in displacing the ice. This arrangement is of practical value mainly with massive solid ice, such as is encountered in the Straits of Mackinac, where the bow screw is still used. Under such conditions, its action is to create a downward suction of the water under the ice as the ship drives into it. But this action is said to be of little effect in the deeply packed slush ice and frozen snow which constitutes one of the principal troubles on the longer routes across the open lake. This ice is sometimes packed clear to the bottom in channels and basins. But a bow screw only makes a hole, perhaps

15 ft. in diameter, which is not of much assistance to a ship of 56 ft. beam. As the result of experience, therefore, the bow screw is not used on the boats of the cross-lake lines.

Another reason for the continued use of the bow screw on the boats of the car-ferry at the Straits is that these boats are built for loading and unloading cars at the bow, instead of at the stern. Consequently, when heading into a landing slip full of ice, the propelling screws are of no effect in dislodging the ice. But the action of the bow screw is to draw water from under the ice, which thus loses much of its support at the same time that the inclined bow or forefoot crushes it down as the stern screws drive the boat forward.

All the boats on the other routes load and unload cars at the stern, and therefore back into the landings, the screws then serving both to pull the boat in and to dislodge the ice. This requires more maneuvering in turning and backing than is required with entering bow first, and there is some risk of damage to the rudder by backing in stern first, but such damage rarely occurs. The stern-loading arrangement is the more convenient, as the broad deck or fantail permits of spreading the tracks better than on the necessarily narrower width at the bow. Further, a vessel with bow open above the main deck would hardly be seaworthy in rough weather on the open lake, when seas breaking on the bow throw volumes of solid water even on the upper deck. However, an Italian car-ferry vessel with bow loading has heavy steel doors closing across the front of the car space, as noted on a following page.

That several new boats have been built in recent years, and some of the older boats reconditioned, may be taken as indications of the importance and growth of the cross-lake railway traffic. This traffic, however, has fallen off seriously during the past few years of depression and railway difficulties.

It will now be appropriate to consider more particularly the several lines and their marine equipment.

Mackinac Car-Ferry Line

The short, but busy and important car-ferry across the Straits of Mackinac, which form the outlet at the northern end of Lake Michigan, was the pioneer car-ferry line, started in 1888, and is notable in three ways: (1) As being the original of all the train ferries; (2) for carrying passenger trains as well as freight trains; and (3) for employing a distinctive type of steamer, having a bow entrance and triple screws. This service is operated by the Mackinac Transportation Company, which is owned jointly by three railways: The Michigan Central and the Pennsylvania terminating at Mackinaw City, on the south side of the Straits, and the Duluth, South Shore & Atlantic terminating at Saint Ignace on the north side. While the distance is only about 8 or 10 miles, the service is especially difficult to operate during the winter, when the ice is not only thick and solid, but is sometimes piled up 12 ft. or more above the water by the action of winds and waves.

The first car-ferry steamer on this route was the "Saint Ignace", which was put into service in 1888 and had a capacity for six passenger cars or ten freight cars. It was 235 ft. long, 52 ft. beam, and had compound engines with cylinders 28 and 52 in. by 40-in. stroke. This boat was followed in 1890 by the "Sainte Marie", 316 ft. long and 62 ft. beam, which could carry 18 freight cars. It was conspicuous by having four funnels, at the corners of a square. The main engine, with cylinders 32 and 58 in. diameter and 48-in. stroke, drove a 12-ft. screw at 100 r.p.m. For the ice-breaker screw in the bow, there was an engine with cylinders 28 and 52 in. diameter and 40-in. stroke. These two boats were of timber construction. The "Saint Ignace" was sold in

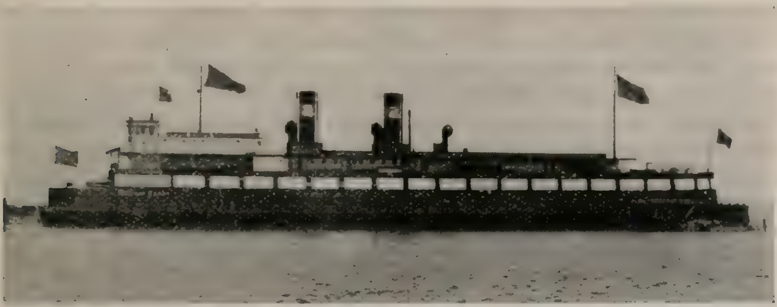


Fig. 1.—Car-Ferry Steamer "Chief Wawatam"; Straits of Mackinac.

1913 and was afterwards burned, while the "Sainte Marie" was replaced a few years later by a larger steel boat of the same name. At present, there are two boats in service; the second "Sainte Marie" and the larger and more powerful "Chief Wawatam", built in 1911. A view of the latter is given in Fig. 1.

Both of these boats differ from those used on the open lake, in that the cars enter and leave at the bow, the stern being permanently closed above the car deck. The purpose of this arrangement is to avoid the difficulty of backing steamers into a landing slip filled with ice, but it would not be practicable for the car-ferry steamers which cross the open lake and have to encounter heavy seas. During the voyage, the bow entrance is partly closed by a pivoted gate forming the bulwark, about 5 ft. high, to exclude waves, spray and ice. In each boat a bow screw is provided to assist in breaking up and dislodging ice, either at the landing or in the Straits. This screw causes a downward and backward current of water, disturbing the support of the ice and throwing it back so that it is thus more readily broken down and thrust aside by the ice-breaking bow, as the twin screws at the stern push the boat forward.

The present "Sainte Marie" of 1,625 tons, is 266 ft. long, 232 ft. on the keel, with 62-ft. molded beam and a depth of 25 ft. below the main deck, while the height from main deck to upper deck it 18 ft. The compound condensing engines for the twin screws have cylinders 32 by 48 in. and 56 by 48 in., while a similar engine for the bow

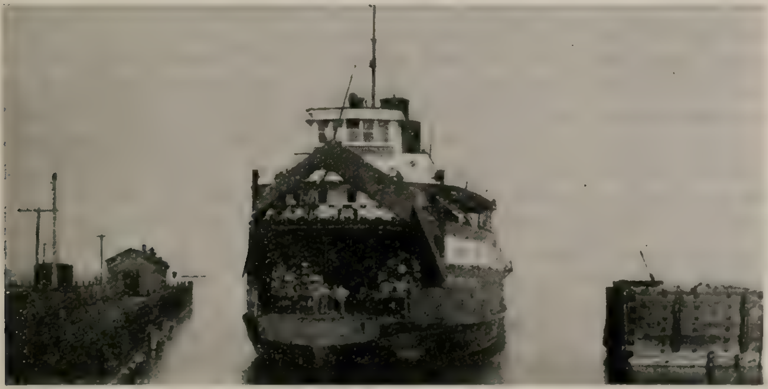


Fig. 2.—"Chief Wawatam" with Bow Bulwark Raised.

screw has cylinders 28 by 40 in. and 52 by 40 in. Steam at 125 lb. pressure is supplied by six return-tube boilers, each 12 ft. 6 in. in diameter and 11 ft. long, with two 43-in. furnaces. This boat can carry ten passenger cars or fourteen freight cars.

The "Chief Wawatam"—the larger boat—is 352 ft. long, 332 ft. 6 in. on the keel, 62 ft. beam and 25 ft. deep with a height of 18 ft. for the train space between decks. The bow entrance is shown in Fig. 2, with the steamer coming into its landing at Mackinaw City. It will be seen that the triangular portion of the bulwark at the bow is raised in readiness for the switching engine to pull the cars ashore. The three engines are all of the triple-expansion type, 2,500 hp., each with cylinders 21 in., 33 in., and 52 in. in diameter and 40-in stroke, running at 100 r.p.m. The two propelling screws are 12 ft. 6 in. in diameter and 14-ft. pitch, while the bow screw, which is of very heavy design, has a diameter of 11 ft. 6 in. and a pitch of 16 ft. All the screws are of cast steel. There are six return-tube boilers, carrying 185 lb. pressure. These boilers are arranged in two batteries, each with a main uptake and funnel. The four lines of rails on the train deck can accommodate 15 passenger coaches or 25 freight cars. It may be noted that these boats ferrying the Straits are shorter, broader and deeper than those which operate on the open lake.

Ann Arbor Railroad Car Ferries

The Ann Arbor Railroad, extending from Toledo, Ohio, to Frankfort, Mich., is of interest as being the first line to operate a car-ferry across the lake, having put two wooden steamers in service in 1892. Each boat had a carrying capacity for 24 freight cars, which were smaller than those of the present day. The boats were 267 ft. long, 52 ft. beam, with 12-ft. loaded draught and a displacement of 2,550 tons. Besides the twin screws at the stern, there was a third screw at the bow, the stem sloping sharply back from a point just below the water line, and then having a short vertical drop to the keel in rear of the screw. This screw, intended to dislodge and break up ice, was of very heavy design. It was not used on later boats, as already explained. Each of the three screws was driven by a compound engine having cylinders 20 in. and 40 in. in diameter and 36-in. stroke.

Steel steamers were added to this line in 1898, 1906, 1910 and again in 1925 and 1927. In 1923 the first of the steel boats, the "Ann Arbor No. 3", was lengthened 48 ft., making it 307 ft. long. At the same time the old compound engines were replaced by triple-expansion engines, with jet condensers and a forced draft system for the boilers. This railway has now five car-ferry steamers. During 1939 its boats made 3,716 trips across the lake and carried 75,000 freight cars.

One of the largest of the car-ferry steamers is the "Wabash", which was put in service by the Ann Arbor Railroad in 1927. This vessel is 380 ft. long overall, 368 ft. between perpendiculars and 37½-ft. molded beam, with a depth of 21 ft. 6 in. from train deck to keel and 17 ft. 6 in. from upper deck to train deck, or 39 ft. in all. The four lines of rails can accommodate 32 freight cars. With full load the draft is 16 ft. and the sea speed is 14 miles per hour. This steamer is illustrated in Fig. 3, and the cross-section in Fig. 4 shows the general arrangement and structural design, which are typical of the Lake Michigan car-ferry steamers. The "Wabash" was built by the Toledo Shipbuilding Company.

Transverse bulkheads divide the hull into eight water-tight compartments beneath the main deck. There is no double bottom, but wing tanks holding 60 tons of water each are provided for trimming the ship to an even keel if the car loads are unevenly distributed. These tanks are served by the ballast pumps. The holds also contain two fresh water tanks of 3,000 gal. each, and a sewage tank of 2,000 gal. to receive the dis-

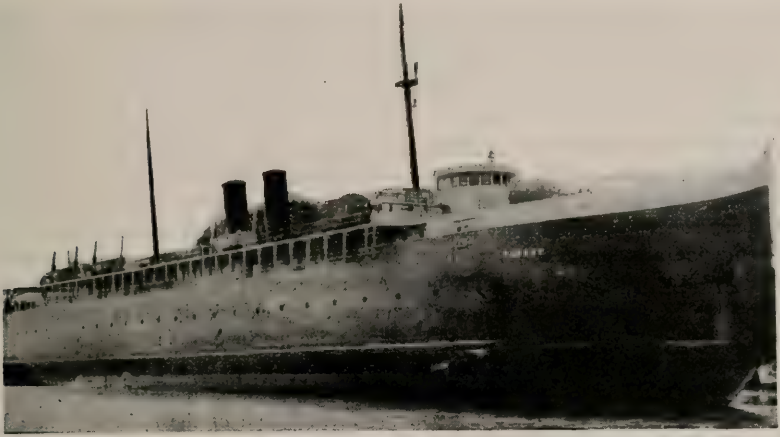


Fig. 3.—Car-Ferry Steamer "Wabash"; Ann Arbor Railro

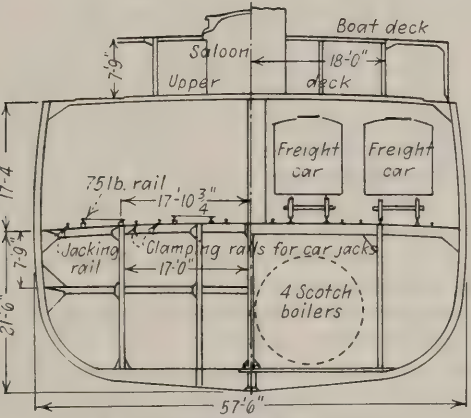


Fig. 4.—Cross Section of Car-Ferry Steamer "Wabash".

charge from all plumbing below the water line, since direct discharge into the lake is forbidden by law. Coal bunkers are arranged on either side of the boiler room.

Four tracks on the train deck extend as far forward as clearance will permit, and end at heavy steel bumpers built into the deck framing. These tracks have 75-lb. rails bolted to chairs or stools, which are steel plates bent to the form of saddles or inverted troughs and are riveted through the plating to the deck beams. They are about 4 in. long, or 8 in. at the rail joints, and of different heights to compensate for the transverse camber of the deck. Outside each track rail and riveted to the deck is a 75-lb. clamping rail to serve as a footing for the inclined screw jacks which engage with the sills of the cars in order to steady them against rolling or swaying on the truck springs due to the movement of the steamer in a seaway.

At the stern, however, the steel deck is covered with 4-in. oak planking bolted to the plating and well calked. Upon this are lines of ½-in. and ¾-in. steel plates on which the rails are laid. This construction makes a convenient decking for motor vehicles in running on and off the boat, although they have to climb over some of the rails unless filler planks are laid between the rails. On the fantail at the stern of the deck, the four tracks begin to converge to meet the two tracks of the landing apron and the approach.

Upon the upper deck is a superstructure about 35 ft. wide and 8 ft. high, the roof beams of which are extended to the full hull width and supported by stanchions at the sides in order to carry a boat deck. In this deck house or superstructure are the saloon, staterooms, ladies rooms, smoking room, dining room, galley and crews' quarters. Staterooms provide accommodation for about forty passengers and some of the cabins are suites, with private parlors and bathrooms. A large number of passengers can be carried on day trips, as on holiday excursions. Steam heat and electric light are provided, while the galley has a cold storage room and a one-ton ice machine.

The bow is high and has a long turtle-back forecastle, connected with the promenade or boat deck by a bridge or gangway. This arrangement is unusual, the upper deck usually extending flush to the bow. Upon the forward end of the boat deck is a house with the officer's quarters, the front of this structure being carried up to form the wheelhouse and navigating bridge. At the after end of the upper deck is a second wheelhouse, which is used by the deck officer when maneuvering and backing the ship to its landing. During the voyage the open end of the train deck is closed by a hinged bulkhead or stern gate, 5 ft. high. This gate is attached to pivoted arms, and is raised by a power winch, so as to span the deck like an arch, and to permit the cars to pass under it. A powerful electric winch to handle the swinging cable of the ship when turning is mounted in the well deck space between the forecastle and superstructure.

The two triple-expansion engines have cylinders 20½ in., 34 in., and 56 in. diameter, by 36 in. stroke, each equipped with a turning or barring engine 6 by 6 in., and a reversing engine 10 by 18 in. Jet condensers have 6-in. turbine-driven pumps for handling the condensate. The propellers are four-bladed screws 12 ft. in diameter, 14½ ft. pitch, revolving outboard. Four Scotch boilers, with three furnaces each, give a total heating surface of 2,750 sq. ft., and carry 185 lb. pressure. They are single ended boilers, and are mounted in pairs, with the firing room between them. Each pair has its own uptake and funnel. An ash ejector of the hydraulic jet type is fitted on each side of the fireroom. Hot-air forced draft on the Howden system is supplied by two engine-driven fans, 66 in. in diameter.

The "Wabash" is the flagship of the fleet. The other boats are 307 ft. long of 2,700 to 3,000 gross tonnage, and each with engines of about 3,000 hp. Of these other

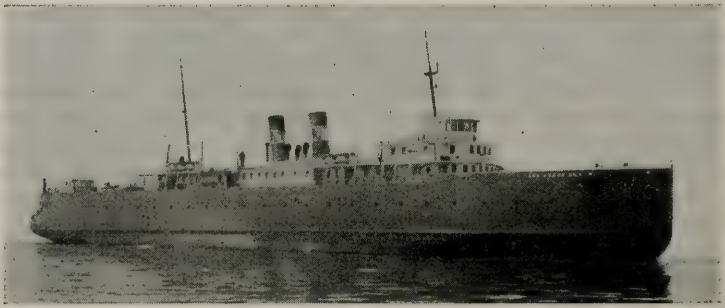


Fig. 5.—Car-Ferry Steamer "Ann Arbor No. 7".

boats, the largest is the "Ann Arbor No. 7", illustrated in Fig. 5, which was built in 1925. She is 360 ft. long and 56 ft. beam, with a depth of 21 ft. 6 in. below the train deck. There is a clear headroom of 16 ft. above the rails of this deck, and the loaded draft is 16 ft. The vessel has a loaded displacement of 6,510 tons; gross tonnage, 2,954; the net tonnage being 1,426, and the cargo capacity 2,240 tons. The two triple-expansion engines, of 1,500 hp. each, are similar to those of the "Wabash." Steam of 185 lb. is supplied by four Scotch boilers, and the bunkers have capacity for 400 tons of coal. The propellers have a diameter of 12 ft., with 15-ft. pitch. With a full load of 28 cars the sea speed is 15 miles per hour. Deck passengers, to the number of 300, may be carried, while 14 staterooms have berths for 28 passengers. The vessel is manned by a crew of 36 men under 8 officers.

Pere Marquette Railway Car-Ferries

The Pere Marquette Railway, which was the second to extend its rail system westward by car-ferry service across Lake Michigan, has now seven boats in this service and one under construction to increase its fleet to eight by 1941. Three routes are operated, from Ludington, Mich., as the head port, to Milwaukee, Manitowoc and Kewaunee, on the west side of the lake. In 1938, the boats carried 100,738 cars in and out of the three west side ports. At Milwaukee, the railroad uses both its own car-ferry terminal and the city's municipal terminal for car-ferries. One of the old boats was built with an ice-breaking screw at the bow, but in operation the screw was found to be a detriment rather than an advantage and it is reported that, after its removal, the boat proved more satisfactory. All the present boats have twin screws, and all but two have triple-expansion engines and Scotch boilers. The exceptions have turbo-electric equipment and water-tube boilers. The latest and largest of the steamers having triple-expansion engines is the "Pere Marquette No. 21", shown in Fig. 6. A comparison of this boat with one of those having electric drive is given in the table on a following page.

Of particular interest and importance is the fact that the Pere Marquette Railway has under construction by the Manitowoc Shipbuilding Corporation the largest

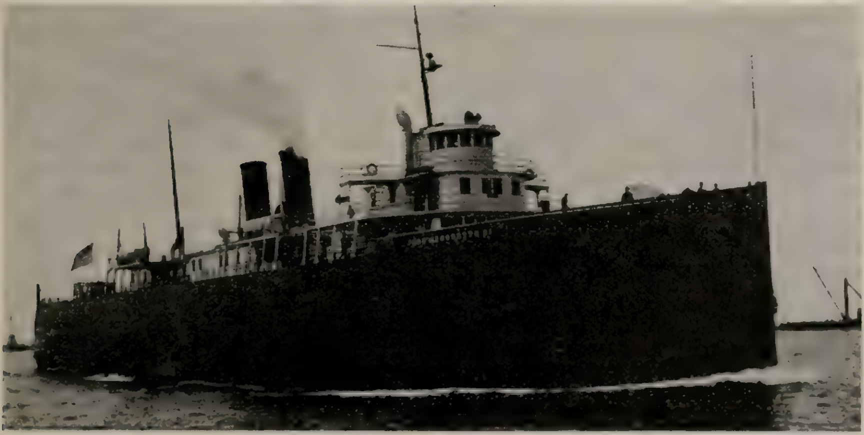


Fig. 6.—Car-Ferry Steamer "Pere Marquette No. 21"

and most powerful car-ferry steamer ever operated on the Great Lakes. It is to be completed by January, 1941, and will have cost about $1,970,000. This steamer, with unusual streamline design in its superstructure, will be 406 ft. long, with a beam or width of 57 ft., a molded depth of 23 ft. 6 in. below the main deck, and a maximum loaded draft of 17 ft. 6 in. Twin screws, with power equipment of 6,000 shaft horsepower, will give the ship a speed of 18 miles an hour. Steam will be supplied by water-tube boilers. Special features include reinforced double bottom, radio compass, and many of the latest safety devices for navigation.

Four tracks on the main deck will have capacity for 34 freight cars. Passenger accommodation, arranged on the upper deck, will include saloons, a large dining room to seat about 60 persons, 12 private parlor suites and 74 staterooms. In view of the heavy and increasing automobile traffic across the lake, a new feature is provision of space for 50 automobiles on the upper deck, access to which will be given by ramps at the terminals. On the present boats, automobiles are carried on the main deck, but the number is limited to the space available after the railroad cars have been placed on the tracks.

TURBO-ELECTRIC STEAMERS.—The two boats which were put in service in 1930, the "City of Saginaw" and "City of Flint", represent a radical development in car-ferry construction both because of their power equipment and of their speed of 18 miles an hour, as compared with 12 to 14 miles an hour for the other boats. They were built by the Manitowoc Shipbuilding Corporation. The "City of Flint" is shown in Fig. 7.

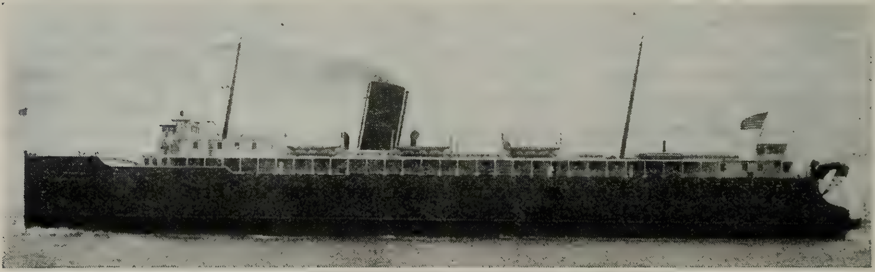


Fig. 7.—Car-Ferry Steamer "City of Flint"; Pere Marquette Railway.

Each steamer has two independent units for the two screws, and the electric equipment is designed with a view to efficient and reliable service under the peculiarly severe conditions incident to driving the vessels through heavy ice in winter. Each unit comprises a turbo-generator set supplying a motor coupled directly to the screw shaft. The a.c. generators are of the 2,300-volt, three phase, 60 cycle type and—with the turbine—they run at 3,600 r.p.m.; but governors reduce the speed to 2,700 r.p.m. when the ship is maneuvering. The a.c. slip-ring motors are of 3,600 hp. each, with a normal speed of 120 revolutions. Each motor is ventilated and cooled by a fan with 25-hp. motor. The propeller speed is varied by means of a resistance connected in series with the rotors, and also to some extent by varying the turbine speed. Electric auxiliaries take current from the main generators through the transformers.

Steam is supplied by four Babcock & Wilcox water-tube boilers with horizontal tubes. They have a total of 20,000 sq. ft. of evaporative surface and 1,200 sq. ft. of superheating surface, and deliver steam at a temperature of 620 deg. F. and at 315 lb. pressure. Mechanical stokers and chain grates do the firing. Coal from the bunkers is

CAR-FERRY STEAMERS; PERE MARQUETTE RAILROAD

	"No. 21" triple expansion	"City of Flint" turbo electric
Length, overall	360 ft.	380 ft.
Beam, moulded	56 ft.	56 ft.
Depth, below main deck	21½ ft.	22½ ft.
Draught, loaded	16 ft.	17 ft.
Displacement, tons	6,000	7,000
Gross tonnage	2,992	....
Net tonnage	1,511	....
Cargo capacity, tons	2,600	2,800
Engines, twin screw	triple expansion	turbo-gen. with shaft motors
Engines, hp. each	1,350 hp.	3,600 hp.
Bunker capacity	350 tons	600 tons
Speed, loaded, miles per hour	14	18
Number of cars carried	26	30
Officers and crew	46	42

fed, automatically, to an inclined chain conveyor, which carries it up to a crusher to be reduced to the proper and uniform size for the grates. From the crusher it is carried to overhead hoppers or bins having tubular spouts, through which it is fed to the stoker magazines. Instead of the usual pair of funnels, all the boilers are served by one large funnel of oval section. While the stateroom accommodation is limited to about fifty passengers, each of these vessels is authorized to carry 500 deck passengers on day-excursion trips.

Grand Trunk Western Railway Car-Ferry

A car-ferry for freight service between Grand Haven, Mich., and Milwaukee, Wis., was started by the Grand Trunk Western Railway in 1906. A terminal company at Muskegon, Mich., built new piers and a cary-ferry landing in 1933, and the railway then transferred its business to that point instead of Grand Haven. The Pennsylvania Railroad also has a terminal at Muskegon and has acquired a half-interest in the Grand Trunk-Milwaukee Car Ferry Company, which is now operated in the interests of the two railroads. At the time this joint ownership was planned, the railroads applied to the Interstate Commerce Commission for permission to operate an additional ferry line between Muskegon and Manitowoc, Wis. This application was withdrawn later, owing, it was reported, to strong objections made by other railways that were already operating car-ferry lines into Manitowoc.

The first boats of the Grand Trunk–Milwaukee Ferry Company were the "Grand Haven" and "Milwaukee", 306 ft. and 338 ft. long, respectively, with capacities of 22 and 24 cars. There are now four boats in service; the "City of Milwaukee", "Grand Haven", "Madison" and "Grand Rapids". The last two, built in 1927, carry about 30 cars each. During the winter of 1929, one of the older boats, the "Milwaukee", was lost with all hands during a violent storm, and no vestige of her was ever discovered. A new boat was ordered in 1930 and was put in service early in 1931.

This latest addition is the "City of Milwaukee", the flagship, Fig. 8. It was built by the Manitowoc Shipbuilding Corporation. All these new boats are of the same general type already described and are practically identical in design and dimensions: 360 ft. long, 348 ft. between perpendiculars, 56 ft. beam and 21 ft. 6 in. deep, with a draft of 10 ft. 3 in. light and 16 ft. loaded. Between decks the clear height of the train deck is 18 ft. 3 in. The hull has frames made of 10-in. rolled steel channels spaced 24 in. between centers and is divided into seven water-tight compartments, with a heavily reinforced ice-breaker bow. Each vessel is of 2,945 gross and 1,490 net tonnage, with a cargo of deadweight load capacity of 2,600 tons.

On the main deck are four lines of rails with total capacity for 30 freight cars. In the superstructure on the upper deck are a saloon and large observation room at the forward end, with staterooms along each side, giving accommodation for 40 passengers. It has also smoking room, women's room and toilet rooms. Beyond the saloon are the purser's and steward offices, dining room, galley, storerooms and crew's quarters.

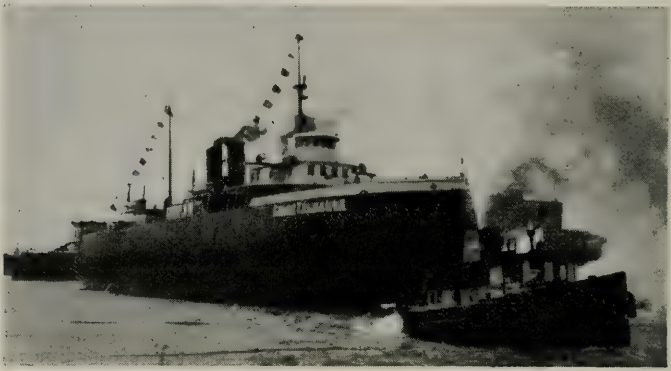


Fig. 8.—Car-Ferry Steamer "City of Milwaukee"; Grand Trunk Western Railway.

At the after end of this deck is a wheel house, from which the ship is handled when turning and backing into the landings. The captain's room and officer's quarters are in a house above the forward end of the superstructure and surmounted by the wheelhouse with its navigating bridge. Officers and crew number together about fifty, and there is cabin accommodations for 24 passengers. Unlike most of the Lake Michigan car-ferries, the Grand Trunk boats do not carry automobiles.

Triple-expansion twin-screw engines of 1,500 hp. each, having cylinders 20½ in., 34 in., and 56 in. diameter, with a stroke of 36 in., give a sea speed of 14 miles an hour. Four Scotch marine boilers carrying 185 lb. pressure are arranged in pairs on opposite sides of a thwartship firing room or stokehold, each pair or battery having its own uptake and funnel. These boilers are 14 ft. 6 in. in diameter and 12 ft. long.

Long-Haul Barge Car-Ferry

An early experiment in long-haul car-ferry service for freight transfer by means of barges was started on Lake Michigan in 1890 by the Lake Michigan Car-Ferry Transportation Co., a subsidiary of the Wisconsin & Michigan Railroad. The cars were carried between South Chicago (where connections were made with several railroads) and Peshtigo Harbor, then located on Green Bay, eight miles south of Peshtigo, Wis. The distance was about 240 miles. There were two fleets, each consisting of a large and powerful steam tug with two barges, each barge carrying 26 cars on four tracks. The barges were 310 ft. long, 44 ft. wide and 10 ft. deep, with a loaded draft of 8 to 9 ft. The round trip was made in 51 hours, including the time for loading and unloading.

This transportation service, which was originated by J. N. Faithorn, did not prove satisfactory, and met with mishaps. Two of the barges were lost in the first few years of operation, and in 1904 or 1905 another capsized, in the Chicago harbor, inside the breakwater. The service was abandoned about 1912.

Part II.—Other American Car-Ferries

On the lower lakes and their connecting channels, and also at different points along the St. Lawrence river, from the lakes to the sea, there are a number of car-ferry lines, operated independently or jointly in the interests of different American and Canadian railroads.

Car-Ferries on the Lower Lakes

Lake Erie.—A car-ferry between Ashtabula, Ohio, and Port Burwell, Ont., 47 miles, is operated by the Pennsylvania-Ontario Transportation Company, in connection with the Pennsylvania Railroad and the Canadian Pacific Railway. This service is handled by the steamer "Ashtabula", which is of the same general type as the car-ferry steamers on Lake Michigan and Lake Ontario, having twin screws, high freeboard and enclosed car deck. The boat is 350 ft. long, 56 ft. 6 in. beam, and has four tracks with aggregate capacity for 26 freight cars (long gondola type). This ferry service is not operated in winter, after the ice has become heavy.

Another car-ferry was operated for some years by the Marquette & Bessemer Dock & Navigation Company, running between Conneaut, Ohio, and Port Stanley, Ontario. This was in connection with the Bessemer & Lake Erie Railway and the Pere Marquette Railway. There was one steamer, the "Marquette & Bessemer No. 2", built in 1910 by the American Shipbuilding Company, at Cleveland, Ohio, and similar in type to the Lake Michigan boats. It had capacity for 30 freight cars, but carried no passengers or automobiles. The crossing, 60 miles, was made in five or six hours.

Ice was troublesome during the winter, and the boat did not run when there was heavy ice in the lake. In 1930, this boat carried nearly 4,800 cars, mainly with coal, coke and steel, as the Bessemer & Lake Erie serves the great coal, iron and steel district around Pittsburgh. This car ferry was established in 1903, but it was abandoned in 1932, under authority of the Interstate Commerce Commission.

A similar service between Conneaut and Rondeau, Ont., was operated by the Pere Marquette at one time, but was abandoned several years ago.

Lake Ontario.—A car-ferry across Lake Ontario, between Charlotte, N. Y., and Coburg, Ont., has been operated for some years by the Canadian National Railways in connection with the Buffalo, Rochester & Pittsburgh (now a part of the Baltimore & Ohio Railroad). The distance is about 58 miles, and the trip is made in about five hours. Ice troubles on this lake are not severe. Coal and general merchandise constitute the principal freight carried, but passengers and automobiles are also accommodated. Of the two steamers, which are very much like those in the Lake Michigan services, the "Ontario No. 1" was built in 1907 by the Canada Shipbuilding Co., and "Ontario No. 2" in 1915 by the Polson Iron Works, at Toronto. They are 318 ft. long and 54 ft. beam. For excursion travel, each boat can accommodate 1,000 passengers. Approximately 6,700 cars in both directions were carried during 1939. The Ontario Car-Ferry Company is the operating concern.

Detroit and Port Huron Car-Ferries

Across the St. Clair river (the name given to the northern part of the channel or strait connecting Lake Huron with Lake Erie), the Grand Trunk Railway operated a car-ferry for freight and passenger trains between Sarnia, Ont., and Port Huron, Mich., on its Montreal-Chicago line. But this was abandoned after the opening of the St. Clair Tunnel under the strait, several years ago.

Similar service across the southern part of this strait, known as the Detroit river, is still maintained by three of the four railroads which are intercepted by this waterway. The boats run between Detroit, Mich., and Windsor, Ont., a distance of ¾-mile. The crossing is made in 8 to 12 min., depending largely upon interference by traffic passing up and down the river. Here the Canadian National Railways (on the Buffalo-Detroit line), the Pere Marquette Railway, and the Wabash Railway, each operate car-ferries for the transfer of passenger and freight cars. The Michigan Central Railroad had a similar service, until it was superseded by the railroad's Detroit River tunnel. All the boats are of the open-deck type. The Canadian National Railways have two boats, the "Lansdowne" and "Huron". The Pere Marquette also has two boats. The Wabash operates three steamers, the "Detroit", the "Manitowoc" and the "Windsor"; all have four tracks, with capacity for 26, 30 and 31 freight cars, respectively.

As the passage is short and in still water, with little trouble from ice, the St. Clair River and Detroit River car-ferry steamers are quite different from those operating in deep water across the open lakes. Except for a narrow superstructure extending for part of the length along each side, the train deck is entirely open. The navigating bridge, with pilot house, is supported on steel portal frames. The older boats were driven by side-wheels, but the more modern boats have screw propellers and are usually double-ended, with screws at both ends. In some cases, as on the "Detroit" and the "Manitowoc" of the Wabash Railway, the four screws are mounted on individual shafts, each driven by a separate engine. Other boats have two continuous shafts and two engines.

The car-ferry steamer "Detroit" was built in 1904 for the Michigan Central Railroad by the Great Lakes Engineering Works, and had originally three tracks spaced 18 ft. between centers, with capacity for 12 Pullman cars or 24 freight cars. It was

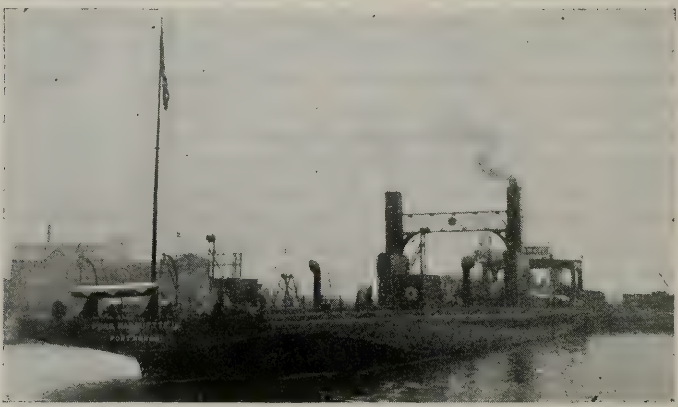


Fig. 9.—Car-Ferry Steamer on Detroit River; Pere Marquette Railway.

single-ended, being loaded and unloaded at the bow, which engaged a three-track landing apron. After the opening of the Detroit River tunnel, the boat was sold to the Wabash Railway, and its deck arrangement was changed to provide four tracks having a total capacity for 26 freight cars. The "Detroit" is 308 ft. long, 64 ft. beam, 76 ft. wide over the deck and 19 ft. 6 in. deep, with a draft of 10 ft. light or 14 ft. loaded. A deck house 90 ft. long on each side contains quarters, etc., and near the bow is a steel tower carrying the pilot house. There are twin screws at both ends, but the ship is single-ended. The four screws are driven independently by four compound engines having cylinders 24 by 33 in. and 48 by 33 in. Four boiler uptakes and funnels are arranged between the tracks. This boat has a speed of about 18 miles an hour.

Typical of more modern boats is the "Pere Marquette 12", built in 1927 by the Manitowoc Ship Building Corporation. It is 400 ft. long over all, 56 ft. beam and 21 ft. deep, with a loaded draft of 16 ft. For operation in either direction without turning, it has twin screws at each end, the screws being on two continuous shafts, each driven by a three-cycle compound engine of 1,000 hp., running at 100 r.p.m. The cylinders are 26½, 40 and 40 in. in diameter, and of 36-in. stroke. There are three tracks, with a combined capacity of 27 freight cars. The boiler uptakes and the funnels are on either side of the middle track. This boat is shown in Fig. 9.

St. Lawrence River Barge Transfer

A car-ferry service handled by a barge or transfer boat and a tug, and having unusual features, is operated by the Canadian Pacific Car & Passenger Transfer Co. on the St. Lawrence river between Prescott, Ont., and Ogdensburg, N. Y., a distance of about a mile. It connects the lines of the Canadian Pacific Railway and the New York Central Railroad. A steamer formerly used was replaced in 1930 with an oil-electric tug, the "Prescotont", lashed to the side of the steel barge "Ogdensburg". The barge is 290 ft. long and 45 ft. wide, 12 ft. 6 in. deep, with three tracks accommodating 17 freight cars.

A special feature of this combination is that the ferry is operated by remote control from the bridge or pilot house of the barge, which is carried by a lofty steel portal frame spanning the open car deck and is electrically connected with the power unit of the tug. This arrangement gives the captain a better view of the landing slips than he would have from the pilot house on the tug. In this way, both the screw and the rudders are controlled from the pilot house. During the winter, severe ice conditions necessitate daily disconnecting of the tug, so that it can be used as an ice-breaker.

Curious Quebec Car-Ferry

A St. Lawrence River car-ferry of exceptional interest was put in service by the Canadian Transcontinental Railway (a government line which is now a part of the Canadian National Railways) to carry passenger and freight cars between Quebec and Levis, about 0.6-mile, in order to provide through connection with Atlantic ports pending the construction of the great Quebec bridge, which was opened to traffic in 1917. The special feature of the "Leonard", the steamer designed for this service, was that it required only very simple landing connections, since it had an "elevating deck" to provide for changes in water level. Another unusual feature was that complete trains were handled, including the locomotives. This steamer, built in England by Cammell, Laird & Company, was delivered to the National Transcontinental Railway Commissioners in August, 1914. When traffic was diverted to the Quebec bridge, there was no further need of the car-ferry, and the boat was sold to the British War Office in June, 1918. It was then taken to England and used during the World War for handling war material and supplies for the Allies, the boat operating between Richborough, England, and Cherbourg, France. It is believed that after the war the boat was sold to the Russian Government for use as an ice-breaker at Archangel.

The "Leonard" was a steel ice-breaking car-ferry, 326 ft. long. It had three screws, two at the stern for propulsion, and one at the bow for ice-breaking purposes. The three tracks were on a movable deck 285 ft. long, supported and operated by ten vertical screws on each side, so that it could be raised to a height of 20 ft. above the normal deck level. After being raised to the level of the landing to receive a load, the deck was lowered to its normal position for the crossing, and then raised to the level of the landing at the opposite side for unloading. The middle track would accommodate a locomotive and three baggage and mail cars, while each side track would accommodate three coaches and three Pullman cars. In handling freight, the three tracks would accommodate 18 loaded cars of 80 tons capacity. Some other steamers of this "elevating deck" type are noted later in connection with the Channel car-ferry between England and France.

The elevating screws on the "Leonard" were suspended by ball bearings on tall columns connected by a framework of struts and bracing. The screws were revolved by worm gearing driven by an engine in the hold. With a live load of 1,285 tons in locomotive and cars, and a total dead and live load of about 1,400 tons, the deck could be raised and lowered at the rate of about 1 ft. per minute.

Hinged aprons at the ends of the car-deck were adjusted to the level of the landing stages, and electric winches were provided for hauling cars on and off the boat, if required. A gangway was carried along each side of the tall steel framework, and at its forward end was the navigating bridge and pilot house. Twin screws for propulsion were driven by a pair of triple-expansion engines of 3,200 hp. At the bow was an ice-breaking screw, with engine of 420 hp., this of course, being disconnected except during the winter.

Hudson River Car-Ferry

About 1881, the New York & New England Railroad, then an independent line, but now a part of the New York, New Haven & Hartford Railroad, arranged with the New York, Lake Erie & Western Railroad for through train service between Boston and the West. This was effected by means of a car-ferry across the Hudson river between Fishkill Landing (now Beacon, N. Y.) and Newburgh. The side-wheel steamer "William T. Hart", built in 1881, began operation on January 1, 1882, and was still in service long after the New England line had been acquired by the New Haven road in 1898. It was sold eventually to J. H. Gregory, of Perth Amboy, N. Y. The car-ferry service of the New York, New Haven & Hartford Railroad in New York Harbor is noted later.

Mississippi and Ohio River Car-Ferries

Until a few years ago there were a number of car-ferries crossing the Ohio and Mississippi rivers, and their tributaries, but with the construction of new bridges a number of these ferries have been abandoned.

Illinois Central System.—The only car-ferry now operated by this road is on the Mississippi river, between Trotter's Point, Miss., and Helena, Ark., a distance of two miles. The side-wheel steamer in this service is 305 ft. long and 91 ft. wide, with two tracks accommodating 14 freight cars. For a maximum range of 62 ft. in water level, cradle inclines provide for connecting the land track with the deck of the steamer at any stage of the river. On the Mississippi side, the incline is 1,383 ft. long, with a grade of 3 percent. The incline on the Arkansas side is 1,696 ft. long and has a grade of 5 percent. Bridges have superseded earlier car-ferries as follows: (1) Vicksburg, Miss., to Delta Point, La.; (2) Brookport, Ill., to Paducah, Ky.; (3) Cairo, Ill., to East Cairo, Ky.; (4) Harahan, La., to New Orleans. The railroad still owns its landing incline and cradle at Baton Rouge, La., but the boats are operated by other lines.

MISSOURI PACIFIC LINES.—Five car-ferries are operated on lines of the Missouri Pacific system for crossings of the Mississippi river: (1) Missouri Pacific Railroad, at St. Louis; the side-wheel transfer steamer "Willard V. King".—(2) Missouri–Illinois Railroad, at Ste. Genevieve, Mo.; the side-wheel transfer steamer, "Ste. Genevieve".—Gulf Coast Lines, at Baton Rouge, La., the side-wheel transfer steamer "George H. Walker".—(4) Natchez & Louisiana Railway & Transfer Co., at Natchez, Miss.; stern-wheel towboat "James Y. Lockwood", handling steel barge "Kirby Beysinger".—(5) Texas & Pacific Railway, at New Orleans, La.; the side-wheel transfer steamer "L. S. Thorne", with similar steamer "Gouldsboro" in reserve for stand-by or emergency service. These landings have incline tracks with traveling cradles, except the one at New Orleans, which has six girder spans forming a single continuous structure adjustable as to grade, as described later.

Typical of many car-ferry steamers formerly operated on the Mississippi river is the above mentioned "Willard V. King", in the St. Louis service of the Missouri Pacific Railroad. This boat, shown in Fig. 10 and Fig. 11, was built in 1910 by the Dubuque Boat & Boiler Co. It is 308 ft. long, 54 ft. beam of hull, and 91 ft. wide over the guards or deck. Each of its two tracks accommodates seven freight cars, which are

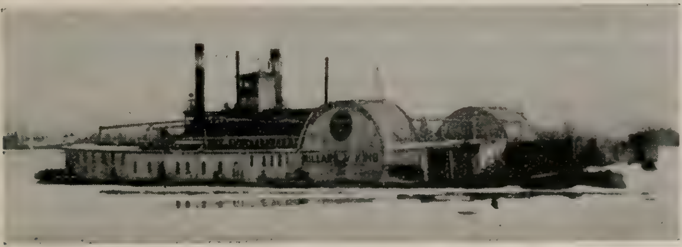


Fig. 10.—Car-Transfer Steamer "Willard V. King" on the Mississippi River; Missouri Pacific Railroad.

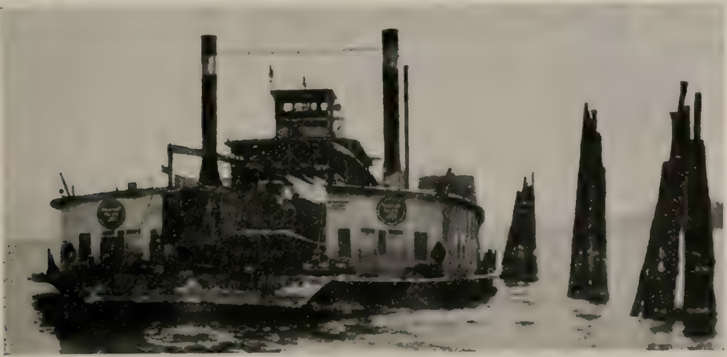


Fig. 11.—"Willard V. King" Entering Car-Ferry Slip.

moved on and off the boat over the bow. Horizontal, high-pressure, non-condensing engines of 1,750 hp., with cylinders 26 in. by 10 ft. drive side wheels or paddle wheels 30 ft. in diameter, having buckets or paddles 16 ft. long. Steam at 100-lb. pressure is supplied by four water-tube boilers 42 in. by 11 ft., of the United States Shipping Board type; each boiler has 409 tubes 3 in. in diameter and 7 ft. 9½ in. long. This steamer has been taken out of service recently, and perhaps permanently, as in February, 1940, the Missouri Pacific began handling its cross-river freight transfer movements at St. Louis over the Municipal bridge.

Gulf Coast Lines Ferry Steamer.—Typical of modern car-ferry steamers for river service is the "George H. Walker", put in operation in 1924 at Baton Rouge, by the Gulf Coast Lines. It is 346 ft. long, 56 ft. beam, 91 ft. 6 in. width of deck (over the guards), with flat-bottom hull 11 ft. deep, and a loaded draft of 6 ft. On each side is a deck house for engines, boilers, paddle-box and quarters, giving a clear deck width of 38 ft. 8 in. for three tracks spaced 12 ft. c. to c. At the bow, the two outer tracks converge to a spacing of 12 ft. 2 in. These tracks give capacity for 12 passenger cars or 24 freight cars.

Geared drive for the side-wheels is a novel feature, each wheel having an engine with inclined opposed cylinders 18 by 25 in.; on the crank shaft is a 21-in. pinion with 21 teeth, gearing with a 125-in. spur wheel with 125 teeth on the wheel shaft. Each engine is rated at 600 hp., with 200 lb. steam pressure and running at 90 r.p.m. The wheels are 30 ft. 6 in. in diameter, with 19 floats or buckets 3 by 14 ft. At full speed of the engines they make 15-12 revolutions per minute. Steam is supplied by two water tube boilers.

Texas & Pacific Railway.—For the crossing between Gouldsboro and New Orleans, the Gouldsboro landing has a trestle incline on which a traveling cradle is moved up and down by a switch engine, according to the level of the river. At New Orleans, however, there was no room for the necessary length of trestle incline, and a suspended steel incline of 270 ft. length is used. This is hinged at the shore end and its outboard end is adjusted to the elevation of the steamer's deck, as described later under the heading of "Car-Ferry Landings."

For regular service there is the car-ferry steamer "L. S. Thorne", 310 ft. long, with hull 56 ft. wide; but the deck is extended on cantilever beams to a width of 87 ft. Its three tracks can accommodate 17 freight cars or eight passenger cars. Train locomotives are not carried ordinarily; switch engines on either side move the cars to and from the boat. The smaller steamer "Gouldsboro", for stand-by or reserve service, has an interesting history. It was converted from the two-turreted Civil War monitor "Chickasaw" of the United States Navy, built by the United States Government at St. Louis, Mo., in 1863, to the designs of James Buchanan Eads, and under his supervision. It is said that the "Chickasaw" design was the first to provide for the manipulation of guns by steam power. The "Chickasaw" played a very important part in the Battle of Mobile Bay. Its iron hull has given exceptional service since it was acquired by the railway company in 1884, and is, no doubt, an example of the virtues of old-fashioned wrought iron.

St. Louis Southwestern Railway.—A car-ferry across the Mississippi river between Cairo, Ill., and Bird's Point, Mo., was operated for some years by this road, which built a transfer incline at Bird's Point. In 1891, the road made a contract with the Illinois Central Railroad for the use of its terminal facilities at Cairo, where a hoist changed the car trucks from 3 ft. to 4 ft. 8½ in. gage, three-rail tracks being used at both places. Another contract was made at the same time with the St. Louis, Iron Mountain & Southern Railway for the use of its transfer steamers.

This car-ferry service was discontinued long ago, probably about 1908, as in September of that year the river bank caved to such an extent as to practically destroy the boat yard and most of the facilities. Then in April, 1909, the transfer incline was washed away by the river, and was never rebuilt. The service was always uncertain, as a high stage of 49 ft. on the river gage at Cairo caused overflow of the tracks at Bird's Point, while very low water (4 ft. or less on the Cairo gage) either interrupted traffic or stopped it entirely.

Texas & New Orleans (Southern Pacific Lines in Texas and Louisiana).—Until the opening of the New Orleans bridge, in 1935, the Southern Pacific ferried complete passenger trains across the Mississippi river on a three-track barge, 441 ft. long and 50 ft. wide. One track held the engine, tender and four cars, while each of the other tracks held five 80-ft. cars. The barge was handled by a steam tug lashed alongside. Its draft was 4½ ft. loaded and 3½ ft. empty. At the New Orleans landing and the one at Algiers (on the west bank) there was a double-track incline consisting of steel girder spans suspended from an overhead structure and adjustable to the level of the ship's deck, as described under the heading of "Car-Ferry Landings". At Avondale, also on the west bank, there was a fixed three-track incline on a trestle with 15-ft. spans and 13-pile bents, except that in the submerged part the spans were 10 ft. and the bents had 15 piles. On the incline the grade was 3 percent, while the traveling cradle had a 3 percent grade ascending towards the outer or river end.

Nashville, Chattanooga & St. Louis Railway.—This road operates a car-ferry on the Tennessee river, between Hobb's Island, Ala., and Gunter's Landing (Guntersville, Ala.), a distance of 21.56 miles. The equipment comprises two stern-wheel steamers and two steel barges 240 by 32 ft., each with two tracks and a capacity for ten freight cars. Cradle inclines provide for connecting the land tracks with the barges at varying levels of the river.

Pacific Slope Car-Ferries

Southern Pacific Company.—Notable among shallow draft car-ferries on inland waters was the "Solano" of the Central Pacific Railway (now a part of the Southern Pacific System) which for many years carried trains across the two-mile width of the Carquinez straits, an arm of San Francisco bay and about 30 miles north of San Francisco. Its service was abandoned with the completion of the Suisun Bay bridge, on a diversion line, in 1930.

This remarkable boat, built in 1879, was of timber construction, and double ended, so that it went back and forth without turning. It had new boilers installed in 1905, and was completely reconditioned in 1915. It was 424 ft. long, and its four tracks, extending from end to end, had capacity for 36 freight cars and two locomotives, or 24 passenger cars and two locomotives.

Sidewheels or paddles were driven independently by two walking-beam engines in superstructures on either side of the deck. Steam was supplied by eight Scotch boilers burning oil fuel and arranged in four batteries forward and aft of the great paddle-boxes, each battery having its own uptake and funnel. At each end were two balanced rudders 11½ by 5½ ft., those at the end which was temporarily the bow being locked in position. With these rudders and the independently operated sidewheels the vessel could be handled readily in a current of about 8 miles an hour. The general dimensions are given in the table. A second boat, the "Contra Costa", was built in 1914, in order that the "Solano" might be overhauled and largely rebuilt in 1915. It was largely a duplicate of the older boat.

In 1880, the one boat carried 2,127 passenger trains and 1,434 freight trains, but in 1925, with two boats in operation, the numbers were 10,695 and 2,277, respectively. In

PACIFIC COAST CAR-FERRY STEAMERS

Car-Ferry Steamers	*Southern Pacific Company*	*Northern Pacific Railway*
Length over all	424 ft.	340 ft.
Beam of hull	64 ft.	42 ft.
Deck width, over the guards, max.	116 ft.	76 ft.
Draft, light, 5 ft.	5 ft.	7 ft.
Draft, loaded	8 ft.	9 ft.
Depth of hull, at center line	17 ft. 8 in.	13 ft. 6 in.
Tonnage, registered	3,540 tons	1,362 tons
Engine cylinders	4 x 11 ft.	3 x 9 ft.
Boilers, diameter, 7 ft.; length	28 ft.	....
Heating surface	19,640 ft.	....
Grate area	288 sq. ft.	....
Paddle-wheels, diameter	30 ft.	28 ft.
Paddle-wheels, width over buckets	17 ft.	8 ft.
Paddle-wheel buckets; number, width	24—3½ ft.	....

1911, 71,586 passenger cars and 93,744 freight cars were carried, but in 1927, the two boats carried 98,262 passenger cars and 148,130 freight cars.

NORTHERN PACIFIC RAILWAY.—In its early days, the Northern Pacific Railway had a car ferry to carry its passenger and freight trains across the Columbia River at Kalama, Wash., with a route distance of 1¼ miles. This also was a sidewheel steamer, and double-ended, so that it had not to be turned. It was fitted with horizontal engines and tubular boilers of the locomotive type. Three tracks converged into one track at each end of the deck, and could accommodate 27 freight cars, 15 Pullman cars or 18 coaches. The general dimensions are given with those of the Southern Pacific's "Solano".

Canadian Railway Car-Ferries

In addition to the lake and St. Lawrence car-ferries already mentioned, two deep-sea salt-water car-ferries on the Atlantic coast are operated by the Canadian National Railways.

The car-ferry across Northumberland strait, from Cape Tormentine, N.B., to Port Borden, on Prince Edward Island, a distance of nine miles, was established in 1915. The steamer "Prince Edward Island" is an icebreaker, 300 ft. long and 54 ft. beam, of 1,110 registered tonnage and 7,000 hp. It has a double track accommodating twelve freight cars. Passenger cars are carried occasionally and during the summer there is through sleeping-car service to Charlottetown, the capital city of Prince Edward Island.

With the increase of automobile traffic, the handling of motor cars so overtaxed this ship that the "Charlottetown" was built in 1931 in order to provide adequate service. The car deck has three tracks with space for 16 freight cars, while the upper deck has accommodation for 40 to 50 automobiles. This ship is 324 ft. long, of 3,385 registered tonnage and 8,000 hp. Both ships have passenger accommodations and they are considered to be the most powerful icebreakers afloat. At each terminal is a steel landing apron, capable of adjustment for a tidal range of 11 ft. Approaches for automobiles are ramps, with adjustable aprons at the level of the upper deck.

The second car-ferry, established in 1907, crosses the Strait of Canso from Mulgrave, Nova Scotia, to Port Tupper, on Cape Breton Island. The two ships "Scotia" and "Scotia II" have each three tracks, the former carrying 18 and the latter 21 freight cars. As the distance is only about a mile, no special passenger accommodation is provided, and the boats have only the one main deck. These boats are of lighter construction than those on the other route, since the service does not require such powerful icebreakers.

Chesapeake Bay Car-Ferries

PENNSYLVANIA RAILROAD.—About 1855, the Pennsylvania Railroad established a car-ferry service across Chesapeake bay to connect the terminal of the Del-Mar-Va division (then the New York, Philadelphia & Norfolk Railroad) at Cape Charles, Va., with railways at Old Point Comfort and Norfolk, Va. (Little Creek terminal), a distance of 24 and 36 miles, respectively. This ferry service is handled by barges or car-floats with tug boats. The barges are 358 and 340 ft. long, of 1,500 and 1,300 gross tonnage, respectively, and each has a capacity for 28 freight cars. They were built at different times by the Maryland Steel Company, the Sun Shipbuilding and Dry Dock Company, and the New York Shipbuilding Corporation.

In addition, there are railway ferries for carrying automobiles and other motor vehicles. The New York, Philadelphia & Norfolk Railroad Ferry Co. operates steamers between Cape Charles, Old Point Comfort and Norfolk, handling passengers, freight and motor vehicles (these last limited to 7 ft. in height). There are three twin-screw steamers; the "Virginia Lee", "Maryland" and "Pennsylvania". The "Virginia Lee", built in 1928 by the Bethlehem Shipbuilding Company, is 320 ft. long, of 2,158 gross tonnage. There is also the Virginia Ferry Company, (of Philadelphia), which operates two ferry boats, the "Delmarva" and the streamlined "Princess Anne". These boats run between Cape Charles and Norfolk (Little Creek), carrying passengers, automobiles and motor trucks; the height limit for the vehicles is 12 ft. 6 in.

New York Harbor Car-Ferries

With so many railways terminating along the water front of the port of New York, both on Manhattan Island and the mainland on both sides, there is of necessity a vast amount of interchange of through cars and also the transfer of cars to specific rail-and-water terminals or to off-track water front pier stations, of which there are 38.

The floating equipment for harbor transfer, owned by the various railroads in 1940, includes 324 steel car-floats for the interchange service. They are 257 to 360 ft. long, usually with three tracks, the largest carrying a maximum of 25 loaded cars. Their light weight is 800 to 1,000 tons, and the loaded weight may be some 2,500 tons. As a rule they are towed in pairs by means of a tug lashed between them. Car-floats serving the off-track pier stations have double tracks with a covered platform between them, at the level of the car floors. Freight is loaded and unloaded as at ordinary freight stations, the cars not being removed from the floats. The car-handling capacity is 17,860 cars daily. In October, 1935, about 76,000 cars were ferried in interchange, and 86,049 in pier station service.

The landing bridges are mainly timber through-truss structures, each spanned by a steel bridge or gantry on which are mounted two hoists, with cables attached to the two trusses of the bridge near the outboard end so as to raise and lower them for adjustment to the level of the car-float.

The ferrying of passenger trains across the harbor was at one time an interesting feature of the harbor traffic at New York. This service was for certain through trains between Boston and Washington, the trains—without locomotives—being transferred around the southern end of Manhattan Island from a terminal of the New York, New Haven & Hartford Railroad at Port Morris, N. Y., on the Harlem river, to that of the Pennsylvania Railroad at Jersey City, N. J. Two steamers were engaged in this service; the "Maryland" and the "Express".

The New England Transfer Company was organized to handle this service, and in 1875 it purchased and reconditioned the steamer "Maryland", 1,395 gross tonnage burthen. This boat had been built at Wilmington, Del., in 1854, and used by the Philadelphia, Wilmington & Baltimore Railroad for car-transfer service across the Susquehanna River between Perryville and Havre de Grace, Md. Its capacity was 20 cars and it replaced the older "Susquehanna" which could carry only five cars. As a matter of history, President-elect Abraham Lincoln was ferried across on the "Maryland" when he made his secret journey from Harrisburg to Washington in 1861. Later in that year, General Butler with his Massachusetts troops seized the "Maryland" and took it to Annapolis. (See "Spy of the Rebellion", by Allan Pinkerton, and "Butler's Book", by Gen. Butler.)

The transfer company sold out to the New York, New Haven & Hartford Railroad in 1887, and the "Maryland" was afterwards used by the railroad in ferrying cars and trains in the harbor at New York. On May 8, 1876, this boat carried the Washington Night Express (later named the Federal) on its first run from Boston to Philadelphia. And on the same date it carried the Philadelphia Day Express (later named the Colonial) which had been put in service on account of the Centennial Exhibition at Philadelphia. This old steamer was burned December 7, 1888, at its dock in the Harlem River at New York. A new "Maryland" of 542 net tonnage was built in 1889 at Wilmington, Del., and went into commission on May 11, 1890. It was in service, ferrying the Federal and the Colonial express trains, until the opening of the Hell Gate bridge over the East River in 1916. Both of these steamers were of the side-wheel type. The "Express" was a twin-screw steamer of 530 net tonnage, built at the same place in 1889. It was sold to W. H. Todd, of Brooklyn, N. Y., in 1913. The "Maryland" also was sold in 1913, to the Home Dredging Company, of Mobile, Ala., and is said to be still in existence.

Hazards due to fog and the dense river and harbor traffic were assigned as reasons for the abandonment of the car-ferry service in 1912. The new land route was at first by a route crossing the Hudson River by the new cantilever bridge at Poughkeepsie, N. Y., 73 miles north of New York City. Later, the completion of the Hell Gate Bridge at New York gave the New York, New Haven & Hartford Railroad access to the new underground passenger station of the Pennsylvania Railroad in New York City, with its tunnels under the Hudson River to the mainland on the New Jersey side.

Florida–Cuba Car-Ferry

From its deep-sea terminal at Key West, Fla., the Florida East Coast Railway in 1914, began operating car-ferry steamers to Havana, Cuba, thus saving time and incidental damage in the rehandling of freight. The distance was 90 miles and the trip was made in about 7½ hours. After the practical destruction of the Key West extension by a hurricane in the fall of 1935, the car-ferry terminal was removed to Port Everglades (near Fort Lauderdale), about 180 miles farther north, making the distance to Havana about 270 miles, which is covered in 20 hours southbound and 17 northbound.

The first car-ferry steamer, put in service in 1915, was the "Henry M. Flagler", 350 ft. long, 60 ft. beam and 20 ft. deep, with twin screws and triple-expansion engines of 3,000 hp., giving a speed of 12 miles an hour with full cargo load. Two other boats —the "Estrada Palma" and the "Joseph R. Parrott"—are very similar, each carrying

26 to 30 freight cars. In design, they resemble seagoing or coasting steamers, but with the stem open above the main deck to permit of running cars on and off the boat. Passenger cars are not handled, and there are no accommodations for passengers, as these are carried by fast steamers from Miami.

While the steamers resemble those on Lake Michigan, the landings are somewhat different. Instead of having the outboard end of the apron suspended from counterbalanced rocking beams by steel hanger bars, it is suspended by cables which pass over large sheaves in steel towers at the side of the landing slip and carry counterweights. Independent cables on drums in the towers provide for raising and lowering the end of the apron. This landing equipment is described later.

The "Seatrain" Car-Ferry System

A novel type of car-ferry, notably different from any previous method, is that which was established a few years ago and now operates between New Orleans, Havana (Cuba) and New York. It is notable on account of the long voyages, the unusual type of steamer employed, and the special method of embarking and disembarking the cars. This service was begun in 1929 by the Seatrain Lines, Inc., with one steamer running between New Orleans and Havana. The distance of about 700 miles was made in 52 hours, the boat making a round trip each week and leaving New Orleans every Saturday. Two larger boats were added in 1932, and the route was extended to New York. At present, a boat leaves New York on Wednesday, and then leaves Havana on Sunday for New Orleans, to arrive on Tuesday. The other boat leaves New Orleans on Wednesday and leaves Havana for New York on the following Friday, arriving on Tuesday. The third and older boat is operated as cargo and traffic require it.

The special purpose of this system of freight transportation is not so much for through travel over the Cuban railways, but rather to eliminate the delay, damage and loss incident to transferring freight from car to steamer and again from steamer to car or warehouse. For the ship, the special feature is that cars are carried on four decks, and instead of being handled through a bow or stern opening, they are raised and lowered through large deck hatchways. For the landing equipment, the special feature is that overhead cranes handle the cars and transport them between the shore tracks and the ship's tracks.

The first steamer for this line, the "Seatrain New Orleans", built in England by the firm of Swan, Hunter & Wigham Richardson, was 427 ft. long, 62 ft. 3 in. beam, of 10,500 tons dead weight, and with a loaded draft of 25 ft. 6 in. Its single screw was driven by an engine of 3,500 hp. Tracks on three decks provided space for 92 cars.

Two larger boats, the "Seatrain New York" and "Seatrain Havana", were built in this country by the Sun Shipbuilding & Dry Dock Company, and were considerably more powerful. They are 478 ft. long over all, 468 ft. between perpendiculars, 63 ft. 6 in. beam, and 58 ft. 3 in. deep, with a loaded draft of 23 ft. at 8,790 tons or 26 ft. at 10,945 tons. The clear height between decks is 16 ft. 8 in. A single screw driven by geared turbines of 8,800 hp. gives a sea speed of 15½ miles per hour.

About 100 cars are carried on four decks, with four tracks on each deck. There are 26 cars on the lower deck or tank top, 26 on next deck, 30 on the main deck and 18 on the superstructure deck, which is assigned usually for empty cars. The equipment and methods of handling the cars by overhead cranes are described more fully later under the heading of Car-Ferry Landings. Two other American steamers were built in 1939 and scheduled to begin operation in June, 1940, on a route between New York and Texas City, Texas.

Car Ferries on Electric Railways

A special development of the car-ferry system was its application in 1912 to an electric interurban line of the Evansville Railways Company, crossing the Ohio river on the ten-mile route between Evansville, Ind., and Henderson, Ky. It utilized inclined landings and cradles built by the Illinois Central Railroad, but abandoned for passenger train service after securing the right to operate over the Henderson Bridge of the Louisville & Nashville Railroad. This electric car-ferry was abandoned in 1928, being replaced by the railway (now the Evansville & Ohio Valley Railway) with bus service over the new highway bridge across the Ohio river.

The boat was about 120 ft. long, 25 ft. beam and 34 ft. wide over the guards, with a depth of 5 ft. and a loaded draft of 3 ft. The hull was of steel and was stiffened by a pair of trusses 12 ft. 9 in. apart, their bottom chords being built into the floor of the hull, while the curved top chords rose about 5 ft. above the deck. A single track was laid between the trusses, and the boat was designed to carry two 45-ton 50-ft. electric cars, though usually the load was a single car.

Two side wheels 15 ft. in diameter were geared to independent six-cylinder gasoline engines of 55 hp. Each end of the boat had a projecting triangular nose, fitting into a corresponding recess in the end of the apron of the landing cradle. Light gallows frames of steel pipe carried the trolley wires above the deck, and a steel tower carried the bridge and pilot house high above the cars. Trolley poles were erected along the inclines and on the cradles, the trolley and telephone wires being wound on drums on a steel tower in order to compensate for the varying length as the cradles were moved up and down the inclines according to the changing river level.

A somewhat similar ferry has been operated since 1916 across Suisun bay, California, by the Sacramento Northern Railway (formerly the Oakland, Antioch & Eastern Railway). The boat is 230 ft. long, with three tracks, carrying six passenger or nine freight cars. Longitudinal shafts, carrying a propeller at each end of the boat, are driven through a clutch by an eight-cylinder gasoline engine of 600 hp., so that the boat can be run in either direction without turning. The distance is nearly ¾-mile.

Car Ferries on Highway Routes

As has been noted already, many of the railway car-ferries carry a limited number of automobiles, motor trucks and other highway vehicles on the car deck, according to the deck space available. And some railways operate special boats for automobile traffic, as noted in regard to Chesapeake bay. There are also a number of car-ferries on highway routes, for the transfer of highway vehicles of all kinds, as well as foot passengers. For a few years past there has been talk of a ferry for automobiles and motor trucks across the south end of Lake Michigan, between Chicago and St. Joseph or Grand Haven, Mich., as a short cut to and from eastern points. But at present this project has not gone beyond the early promotional or paper stage.

Straits-of-Mackinac Ferry.—By far the most important of ferries established for handling highway traffic is that across the Straits of Mackinac, at the head of Lake Michigan, which has been operated since 1923 by the Michigan State Highway Department. It was established between Mackinaw City and St. Ignace, Mich., on account of the heavy tourist traffic in automobiles at the crossing, and in recent years the traffic has increased to enormous proportions. Most of the railway car-ferries on Lake Michigan, including the one crossing the Straits of Mackinac, handle such automobiles and other highway vehicles as they can accommodate on the car deck, but so many busy highway routes converge at the Mackinac crossing that this railway car-ferry could handle only a small fraction of the summer traffic. Even with three boats in service for highway traffic exclusively, carrying 50 to 85 vehicles on each trip, there were often as many as a hundred cars in line, waiting for their turn to get on board. The number of boats in service was reduced in the autumn, as traffic decreased, and formerly all were laid up during the winter on account of the severe ice conditions, and the limited amount of business, the State Highway Department then arranging with the railway car-ferry to handle the highway traffic. In 1939, however, there were five boats in the highway ferry service, as noted in the accompanying table:

STEAMERS OF MICHIGAN STATE FERRY

Steamers	*Car Capacity*	*Length*	*Beam of Hull*	*Depth*
St. Ignace	65	172 ft. 2 in.	44 ft.	12 ft.
Mackinaw City	65	172 ft. 2 in.	44 ft.	12 ft.
Straits of Mackinac	75	196 ft.	48 ft.	12 ft.
City of Cheboygan	88	259 ft.	52 ft.	19 ft.
City of Munising	115	338 ft.	56 ft.	19 ft. 6 in.
Ste. Marie*	80	266 ft.	62 ft.	25 ft.

* This is the railway car-ferry steamer already described, which was leased for winter operation as an ice-breaker to handle highway vehicles.

From 10,119 automobiles, 141 motor trucks and 65 trailers during the season of 1923, the service reached its peak in 1939 with 243,734 automobiles, 13,598 motor trucks, 20,890 trailers, 1,624 buses, and 397 motor-cycles, or a total of 280,243 vehicles. The number of passengers increased during the same period from 2,418 to 478,850, while the receipts rose from $29,906 in 1923 to $509,296 in 1939.

Two of the automobile ferry boats, the "Saint Ignace" and the "Mackinaw City", are 175 ft. long and 45 ft. beam, with a loaded draft of 10 ft. Above the water line, the hull flares outward to give greater width of deck. Each boat has twin screws and two engines of 275 hp. each, giving a sea speed of about nine miles per hour. The "Straits of Mackinac" is somewhat larger, and has a single screw, but its engine is of 1,200 hp. and gives a speed of more than 12 miles an hour. From dock to dock the distance is about nine miles, and the trip takes 50 to 60 min. depending partly on the wind and weather.

Since these boats have a short route and do not traverse the open lake, although there is rough weather at times, the car deck is not entirely covered. There is a forward well deck protected by a short high forecastle, while aft of this the car deck is covered by an upper deck with accommodations for passengers. To increase the car capacity, however, the well deck was later covered by an extension of the upper deck, the cars being handled by an elevator. This arrangement, however, caused considerable delay, as only one car could be handled at a time and all cars had to cross the main deck in going to and from the elevator. To provide for greater speed in loading and unloading the double-deck boats, the landing at each end of the run has been equipped with electric elevators carrying one car at a time. In this way, the upper deck can be loaded and unloaded without interference with the similar operation on the main deck. Each boat has two wide gangways on each side of the forward and after decks respectively. These gangways are used simultaneously, and loading may begin at one gangway before all the cars have been run off at the other gangway. A narrow central structure divides the middle part of the main deck into two roadways, and in this structure are the stairways to the upper deck and engine room, the ventilators and uptake to the funnel. Saloon and toilet facilities are arranged on the upper deck, and over this deck is a boat or promenade deck.

At Mackinaw City, a causeway or embankment leads to a triangular pier-head, so built as to accommodate three boats at once. On one side of this causeway land has been filled in to provide space for about 1,000 cars to park during visits or while waiting to cross the ferry. At St. Ignace, the boats lie alongside a wharf which provides two landings and has a connected parking space. At both terminals, hinged steel aprons connect the landing ramps with the gangways on the main car deck, and elevators handle automobiles for the upper deck.

Irish Sea Motor-Car Ferry.—A ferry for automobiles and other road vehicles is operated across the Irish Sea, about 30 miles, by the London, Midland & Scottish Railway, of England, its terminals being at Stranraer (Scotland) and Larne (Ireland). The vessel put on for this service in 1939, the "Princess Victoria", is 300 ft. long, and 48 ft. beam, of 2,197 gross tonnage. Twin screws with oil engines aggregating 5,000 shaft hp. give a 19-knot speed. The boat can accommodate 80 automobiles and motor trucks, and several hundred passengers. Loading and unloading is done at the stern. The main or car deck is covered by an upper deck which extends to within a few feet of the stern, but the side plating is continued around to the stern, leaving only an opening for cars to pass on and off the main deck. There is no movable bulwark to close this opening at the end of the deck, but under the end of the upper deck there are high doors which close the stern opening during the voyage. Such doors to close the end of the car space are not used on any American car-ferry vessels, but are used on the cross-channel ferry steamers of the Southern Railway, of England, and on the Italian boats for the Sicily crossing. The clear height of the car space of the "Princess Victoria" is 12 ft. 6 in., in order to provide for large motor trucks. The landing aprons for this ship, automatically adjustable to movements of the ship, are described later under the heading of "Car-Ferry Landings".

Channel Ferry for Automobiles.—A cross-channel ferry for automobiles was put in service in 1936 by the Belgian State Railways for the special purpose of encouraging American and English tourist travel throughout Europe. For this purpose the boat was named the "London-Istanbul". It was operated between Dover (England) and Ostend (Belgium). (See Appendix)

Part III.—Foreign Railway Car-Ferries

In Europe, Asia, Africa and South America there are a number of car-ferry links in railway routes, some crossing broad rivers that intercept the rail lines, others connecting the rail lines on islands which constitute a part of the country, and still others connecting the railways of different countries, for international train service. The longest trips are those from England to Belgium, 95 miles; between two of the islands of Japan, 70 miles, beween Germany and Sweden, 66 miles, and between Denmark and Germany, 28 miles. There is a longer river route in South America, but it is a "longitudinal" line instead of a river crossing, the boats connecting an up-river terminal point with the city of Buenos Aires, on the coast. The boat service thus parallels the rail line of another company and offers competitive service. Mention has been made already, under Historical Notes, of car-ferries proposed in recent years to cross the Danube river, connecting the state railways of Bulgaria and Roumania; and to cross the Bosporus, connecting the European and Asiatic railway systems. As in the United States, the type of steamer depends upon whether the service is for river or open-sea conditions. In no case are the open-sea conditions of operation as severe as on Lake Michigan, with its storms, long distances and heavy ice and its heavy traffic.

English and Continental Car-Ferries.—Projects for car-ferry connections between the railways of England and continental countries have been promoted from time to time. One of the earliest of these, in 1862, was for a service between Dover, England, and Calais, France. Another in 1872, proposed to connect Dover and Copenhagen, Denmark. The steamers for the latter were to be 245 ft. long, and in order to provide for changes in tidal level the cars were to be handled by hydraulic elevators at the landings, the range being 23 ft. at Dover. But the English government refused to permit the construction of the necessary terminals and landing works in the harbor at Dover. This project was succeeded by several others for routes between English and French ports, but none of these received the necessary approval of the English government. During the World War, however, some more direct means of transportation than ordinary steamer service was needed for handling English military materials and supplies to the armies at the front. Three special steamers were built in 1916 and 1917, and car ferries were then operated on different routes to France: Richborough (near the mouth of the Thames) to Calais; Richborough to Dunkerque, Southampton to Dieppe, and Richborough to Cherbourg. As commercial developments of these services, for connection with the continental railway systems, one English railway now operates a car-ferry line between Harwich (or Parkeston Quay), England, and Zeebrugge, Belgium; and another railway operates a line between Dover and Dunkerque.

Harwich-Zeebrugge Car-Ferry.—After the World War, three of the steamers built for this military car-ferry service were purchased by the Great Eastern Train Ferries Company and were put in regular operation, under the management of the London & Northeastern Railway, between Harwich (England) and Zeebrugge (Belgium), a distance of about 95 miles. With the world-wide depression, the ferry traffic declined seriously, from 120,644 tons in 1931 to 61,345 tons in 1932. In 1933, therefore, the company sold its interests and equipment to the railway company. The cars are received from and distributed to various parts of Europe. Among special rolling-stock equipment built for the Harwich-Zeebrugge service is a type of large ventilated box car on four-wheel trucks, built by the Hungarian State Railways for the transportation of fruit, vegetables, poultry and other perishable freight from Hungarian points direct to English markets. The Italian State Railways also built refrigerator cars, containers, and steel cold-storage containers adapted to be mounted on flat cars for handling smaller shipments of perishable freight on this route. The containers are about 7 by 8 ft. in plan, and have arched roofs giving a height of 6 ft. 6 in. at the sides and 8 ft. at the center. Double walls and roof of welded steel have an insulating filling of cork slabs.

The three vessels on the Harwich-Zeebrugge route are 363 ft. 6 in. long over all; 350 ft. between perpendiculars; 58 ft. 6 in. molded beam, and 61 ft. 6 in. wide over the fenders. Between the main or car deck and the upper deck the height is 16 ft. The molded depth from car deck to keel is 17 ft. and the mean draft, loaded, is 9 ft. 6 in. It will be noted that the vessels are very shallow as compared with the Lake Michigan boats of 16 ft. draft, the light draft being made necessary by harbor conditions. With their light draft and large width the English boats make considerable leeway with a heavy beam sea and wind, but they are said to be good sea boats, maintaining a regular daily service in all weathers and being held up only by fog. (These boats are shown partly in Figs. 26 and 27).

Unlike the American seagoing car-ferry steamers, the track deck or car deck is largely open, instead of being covered by an upper deck. At the bow there is a short forecastle, carrying lifeboats, etc. Amidship is another short upper deck, with superstructure containing the captain's accommodations, wireless house and chart room. This in turn carries the flying bridge on which is the wheelhouse. For the remainder of the ship's length the car deck is not covered. However there is a high freeboard to within a short distance from the stern, since along each side of the ship is a narrow superstructure carrying a strip of deck at the level of an upper deck, and near the stern these are connected by a bridge for observation when maneuvering or going astern. Twin rudders facilitate the maneuvering.

There is no central enclosure between the tracks (as in most of the American boats) supporting the upper deck and containing the boiler uptakes and the companionway for access to the upper deck and the engineroom and other facilities on the hull. On the Harwich boats the companionways and uptakes, with the oval funnels, are formed in narrow superstructures along each side of the car deck and under the service decks already noted. This arrangement of uptakes and funnels at the sides of the vessel was used in one of the early American boats on the Great Lakes.

Nor is a stern gate or bulkhead provided to prevent heavy following seas from breaking over the car deck as in the case of American stern-loading car-ferry steamers. However, it is stated that there has been no case of seas coming aboard over the stern of the car deck. Nevertheless the new and large steamers for the cross-channel service between Dover and Dunkerque have not only movable stern bulkheads but also doors to close the after end of the car space. No ice is encountered on the North Sea route.

Each of the Harwich steamers has twin screws driven by triple-expansion engines of 1,500 hp. each, running at 170 to 180 revolutions per minute. Their cylinders are 18, 29 and 47 in. in diameter, with 27-in. stroke. The screws are of 9 ft. diameter, with pitch of 10 ft. 9 in. Steam at 180 lb. pressure is supplied by four multitubular Scotch boilers, 12 ft. 6 in. in diameter and 12 ft. long, each with two furnaces. Coal fuel is now used, but during war service the boilers were fired with oil in order that there might be no smoke to make the ships conspicuous to enemy craft. There is a bunker capacity of 102 tons. No trimming tanks are formed in the hull. The sea speed, with full load, is 13½ knots. The displacement is 3,777 tons; gross tonnage, 2,683 tons; net tonnage, 1,085 tons. Cargo capacity (cars and freight), 1,110 tons.

On the open car deck there are four tracks, with effective lengths of 317 ft. for the middle tracks and 224 ft. for the two side or wing tracks. These converge into two tracks at the stern for connection with the landing tracks. The track capacity is 56 cars of 10 tons capacity or 37 of 20 tons capacity, these being mainly the short freight cars common on European railways, but including also long cars on trucks. No sleeping cars or passenger coaches are carried, and there is no accommodation for passengers. The complement includes the captain, two officers, four engineer officers and a crew of 30.

At the landings, a connection is made between the shore and ship tracks by a 200-ton bridge whose girders are hinged at the shore end, while their outboard ends rest on the stern of the ship. When not in use, the outboard end of the bridge is raised by electrically operated hoists, on an overhead gantry frame. The sheave of the multipart tackle carries a massive spreader or cross frame which spans the bridge and has its ends attached to connections on the girders. This whole construction is much more massive than that commonly used for American car-ferries. The track deck between the girders is swung loose on bolts so that it can accommodate itself to the varying list of the ship as cars are pushed on or pulled off the tracks. The landing bridges are of such length as to limit the grade to a maximum of 5 percent. The steamers were built by Armstrong, Whitworth & Company, and the Fairfield Shipbuilding Company.

STRAITS OF DOVER CAR-FERRY.—Projects for car-ferries to cross the Straits of Dover, commonly known as "the Channel", in order to connect the railways of England and France, have been almost as persistent and perennial as those for a Channel Tunnel. Such a tunnel has been proposed for many years, but for military and other reasons the English government has not permitted any of them to pass beyond the paper or promotional stage, except that early experiments with tunneling machines were allowed. A car-ferry line, however, materialized in 1936. From the success of this service there seems little encouragement for promotion of a tunnel scheme. The cost for boats and port or landing facilities would be but a small fraction of the cost of a 36-mile submarine tunnel, while car-ferry facilities and equipment could be made ready in a few months, as compared with several years for the construction of a tunnel.

In 1862, a car-ferry was proposed by Evan Leigh, an engineer who had invented a special type of steamer for the purpose, and he exhibited a model at the International Exhibition in London that year. A project based on this plan was promoted by Sir John Fowler, a leading engineer, but it was killed by government opposition on the score of danger to national defense (as in the case of the Channel tunnel projects). The same result ended the revival of the car-ferry project in 1870, when Sir John Fowler and Scott Russell, another noted engineer, proposed a service of 20-knot side-wheel steamers 450 ft. long, 57 ft. wide, and 80 ft. wide over the main deck. Passenger cars were to be under cover and placed at platforms giving access to saloons and restaurants, but freight cars were to be on an open part of the deck. As again revived in 1883, twin-screw steamers were proposed, having tracks extending from end to end of the deck, and with sides carried up for a high freeboard, but with hinged sections of plating to form openings for the tracks at both bow and stern. The same general project was revived at different times between 1901 and 1905.

A suggestion for the 1903 project was the use of a steamer with "elevating deck" supported on hydraulic cylinders, giving a vertical travel to provide for the changes in tidal level, about 23 ft., so that in loading and unloading cars the deck would be adjusted to the level of the tracks on the quay. For the voyage, the deck would be lowered to the main deck level. The steamer was to be 320 ft. long and 54 ft. wide, having capacity for 14 passenger cars, and engines giving a speed of 15 knots. This design was a development of the car-ferry steamer "Finneston", built by Wm. Simons & Co. for service across the River Clyde at Glasgow in 1890. Its deck was 80 ft. long and 43 ft. wide, with two tracks placed along the sides, while passengers and horse-drawn vehicles were accommodated in the central space. It could carry ten freight cars, 300 passengers and ten horse vehicles. During its first six months service it is said to have carried 444,480 passengers and 75,650 vehicles of 1 to 20 tons weight. As noted already, a larger car-ferry steamer of this type was put in service on the St. Lawrence by the Canadian government railways.

After 1905, the Channel car-ferry project slept apparently until the exigencies of war led to its revival and its actual establishment, as noted above. Three steamers were built, which were afterwards used in commercial service, while the Canadian car-ferry "Leonard" was brought over and used for the same purpose.

In the successive projects for a Channel tunnel, the Southern Railway (England) had been interested for many years, but with the very definite rejection of the scheme by the British Government in 1929, the railway company turned its attention to a train-ferry service in conjunction with the French railways as the next best means of direct connection. Various plans were considered, but then the financial crisis and commercial depression made it doubtful whether the project would be successful. In the meantime, however, the Harwich-Zeebrugge ferry to Belgium was doing good business, and French interests became insistent for a ferry serving France.

Eventually, the Southern Railway decided to proceed with its project for a car-ferry service between Dover and Dunkerque, a distance of about 50 miles. This was put in operation in 1936. The purpose of this service is twofold. First, to provide a regular ferry service between England and France, not dependent on tide conditions, as an offset to the service between England and Belgium. Second, to improve and expedite the transport of traffic being handled by the railway company's cargo steamers, entailing a double handling of freight at the French and English ports.

A minor difficulty in through routing was a slight difference (under half an inch) between the track gages of the English and French railways. A greater difficulty was the difference in loading gages, the width of French passenger cars being almost 10 ft., while that of cars on the connecting English line was 8½ ft. Special sleeping cars were built therefore in France for the international service; 63 ft. long and 9 ft. wide, with a height of 12 ft. 9 in. above the rails. Special freight cars were also built.

This Dover-Dunkerque ferry service differs from that of the Harwich-Zeebrugge line in that passenger cars and passengers are carried, together with automobiles. The railway service includes sleeping cars to and from several European cities. These cars are about 63 ft. long over couplers. The three car-ferry steamers built in 1933–34 resemble large coasting steamers for freight and passengers, and—like the American boats on the Great Lakes—have the car deck entirely covered. One of them is shown in Fig. 12. In addition to the American type of moveable stern gate, which is about 5 ft. high and forms an extension of the bulwarks around the stern of the car deck, these English boats have high steel doors which shut in the car deck at the end of the upper deck, leaving the extreme end of the car deck practically open as shown in Fig. 13. This provision is made on account of the rough cross seas sometimes encountered on the Channel passage.

The three steamers for the Southern Railway are 360 ft. long, 60 ft. beam, 63 ft. over fenders, and 20 ft. molded depth from car deck to keel, this deck being 7 ft. 6 in. above the water line. Between the car deck and upper deck the clearance is 15 ft. 6 in. The loaded draft is 12 ft. 6 in., with the full cargo capacity of 1,200 tons. A bow rudder is used to facilitate maneuvering, as the vessels have to turn round and go stern-first into their landing berths. Twin screws driven by steam turbines aggregating 5,000 hp.

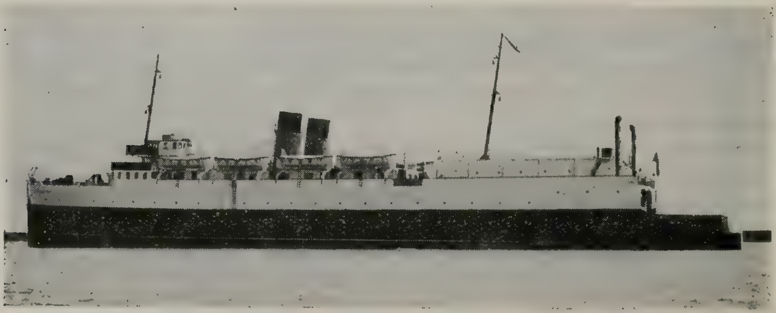


Fig. 12.—Car-Ferry Steamer "Twickenham Ferry"; English–French Channel Service.

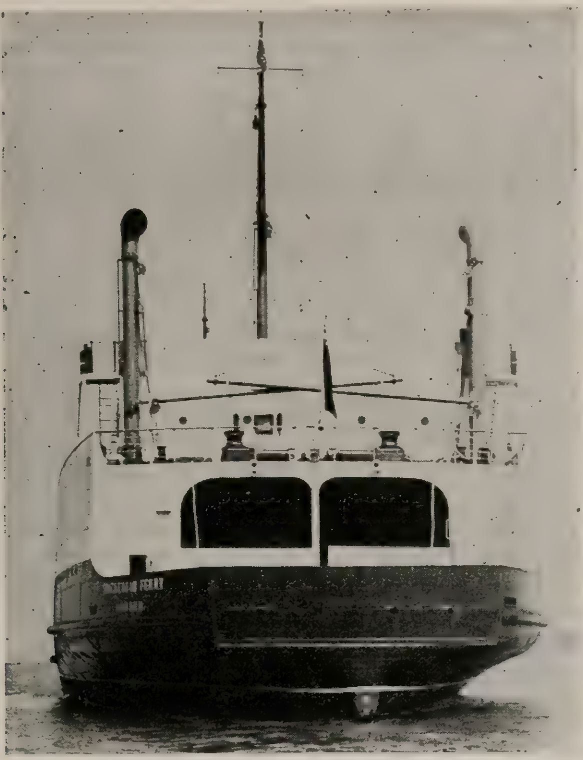


Fig. 13.—Stern View of "Twickenham Ferry", Showing Doors Closing Car Deck.

give a speed of 15 to 16½ knots. Steam is supplied by four water-tube boilers with mechanical stokers. Two longitudinal enclosures between the outer and inner tracks contain the stairways, boiler uptakes, etc., so that the two funnels are placed on a transverse line instead of on the center line. Hopper-bottom coal cars can deliver their contents directly through deck hatches into the bunkers. (See Fig. 26.) One of these boats, the "Shepperton Ferry", has mechanical stokers for the boilers.

Four tracks on the car deck accommodate 40 freight cars—averaging 25 ft. long over all, or 12 sleeping cars and two baggage cars. A garage on the upper deck has a capacity of 25 automobiles, and as this garage is isolated it is not necessary to drain the gasoline tanks of the cars. Automobiles may also be carried on the car deck, for which purpose the spaces between the rails are filled level with the rail heads. For the convenience of train passengers, platforms at car-floor level are provided between the inner and outer tracks. The steamers were built by Swan, Hunter & Wigham-Richardson. The English and French landing arrangements are described later.

Calais-Harwich Car-Ferry

The first car-ferry service between France and England was established by French enterprise, in order to compete with the English-Belgian service. This line, between Calais and Harwich, is operated by the Compagnie Francaise des Ferry-Boats, in connection with the Northern Railway of France and the London & Northeastern Railway. It has utilized one of the boats of the latter railway. At one time this company proposed to change its English port to Richborough, on the River Thames, reducing the length of voyage from 85 miles to 35 miles. This port, served by the Southern Railway, was developed during the World War for the military car-ferry service. But as the Southern Railway has now established a car-ferry line of its own, with port at Dover, on the coast, it is not probable that the Richborough terminal will now be utilized by the French company.

Car-Ferries on the Baltic Sea

Car-ferry services between Continental and Scandinavian countries, and between the mainland and islands of Denmark, were developed from earlier steamer services, which had been operated in some cases by the railways, but more generally by steamship companies. Fast steamers were run between Malmo (Sweden) and Stralsund (Germany), in 1855; and between Rostock and Nykoping (Denmark) in 1863. These were followed by others. Side-wheel, single-track car-ferry steamers of 8-knot speed were introduced by the Danish State Railways for crossing the Little Belt in 1872 and 1877. Their Oddesund and Great Belt car-ferries followed in 1883, and the Masnedo-Orehoved car-ferry in 1884.

In 1903, the ordinary steamer service between Gjedser (Denmark) and Warnemunde (Germany) was converted into a car-ferry service by joint agreement of the Danish State Railways and the (then) Mecklenburg State Railways of Germany. Four car-ferry steamers were put on, and took away much traffic from other lines, so that the Swedish and German railways changed the Tralleborg-Sassnitz steamer service to a car-ferry. In 1913, the various Baltic car-ferry lines made 4,066 trips between Gjedser and Warnemunde, 45 miles; 3,334 trips on the 18-mile run between Copenhagen (Denmark) and Malmo (Sweden), and 2,234 trips between Tralleborg (Sweden) and Sassnitz (Germany), 66 miles.

Denmark's Railway Car-Ferries

The railway system of Denmark is interrupted by a deeply indented coast line, having wide inlets which extend far inland; and in addition it has to serve a number of islands. Owing to these conditions, car-ferries have been used extensively for nearly 70 years by the Danish State Railways to link up their lines. In very recent years, however, some of the ferries have been superseded by bridges, the expense of which was justified by the increasing traffic and the saving in time and trouble of the ferry crossing.

For the crossing of the Little Belt to the island of Fyn, between Fredericia and Strib, side-wheel, double-ended 8-knot car-ferry steamers, with single track on an open deck, were built in 1872 and 1877; others for the Oddesund crossing in 1883; the Great Belt crossing, Nyborg to Korsor, in 1883, and the Masnedo-Orehoved crossing in 1884. In 1898, there were 15 boats in the Baltic service, 12 of them of the side-wheel or paddle-wheel type. They were double-ended, so as not to require maneuvering and reversing; two tracks were laid on an open deck between deck-houses on either side. Steel portal structures spanning the deck carried the navigating bridge and wheel house.

In 1904, Denmark had seven car-ferry routes, operated by six large and twelve smaller side-wheel steamers. The larger boats, with double-track decks, were of 435 tons and 1,600 hp., for a speed of 13 knots. The others, each with a single track extending the full length of the deck, were 190-ton boats of 500 hp., for 10 knots speed. The hinged landing bridges were 65 ft. long. Of the four boats put on between Gjedser and

Warnemunde (Germany) in 1903, two were driven by side wheels and two by twin screws; all were 250 ft. long and 60 ft. beam, with a draft of 12 ft. for the side-wheelers and 13 ft. 6 in. for the twin-screw boats.

Until 1935, the Danish State Railways had eight car-ferry routes, including two to Sweden and one to Germany, as listed in the accompanying table. There were also four car-ferries on private railways, one of these being a meter-gage line. In 1935, the Great Belt crossing, between Korsor and Nyborg, had three fast railway car-ferry boats and one for motor cars or automobiles; all of these had twin screws and oil engines. With the opening of the Little Belt Bridge in 1935, the Fredericia-Strib ferry (three miles below the bridge) was eliminated; and in 1937 the opening of the Storstrom Bridge eliminated the Masnedo-Orehoved ferry. More recently a line between Redby and Fehmarn has been proposed. Heavy ice delayed and even stopped some of the lines during the very severe weather early in 1940.

CAR-FERRY LINES; DANISH STATE RAILWAYS

	Miles
Korsor-Nyborg	16.12
Elsinore-Helsingborg (Sweden)	6.20
Glyngore-Nykobing	4.65
Masnedo-Orehoved	4.34
Strib-Fredericia	3.41
Oddesund N-Oddesund S	3.10
Gjedser-Warnemunde (Germany)	28.00
Copenhagen-Malmo (Sweden)	18.60

On the Gjedser-Warnemunde route, opened in 1903, complete trains of day coaches, sleeping cars and baggage cars are carried, but without the locomotives. On some of the shorter and less important routes, the day coaches are not carried, their passengers walking to the ferry. The Gjedser route is in open sea, but the others are in more or less sheltered waters. Ice-breaking steamers are operated in winter in order to enable the ferries to maintain continual service. Some of the older and smaller boats are double-ended and have only a single track, with no deck over the track deck. Cars are pushed on at the stern and pulled off at the bow. Others have two and three tracks, with extensive accommodation for passengers—railway and ferry—on the upper deck. Automobiles are carried on the track deck. On the Korsor-Nyborg route are vessels with two and three tracks. On the Gjedser route are Danish boats with two tracks and German boats with three tracks.

The largest of the car-ferry boats is the "Storebaelt", built in 1938 for the Great Belt crossing, (Korsor-Nyborg). It is 346 ft. long, and has three tracks and twin screws driven by oil engines. Next to this in size is the "Nyborg" built in 1931 for the same crossing, and having a length of 333 ft., beam 56 ft. 6 in.; greatest width over fenders, 58 ft.; loaded draft, 13.12 ft., with car deck 8 ft. 6 in. above the water line. The three tracks have a total length of 804 ft., and can carry 30 ordinary Danish freight cars. Twin screws are driven by a pair of 8-cylinder diesel engines having a combined power of 3,400 indicated horsepower or 2,800 brake horsepower—at 160 r.p.m., giving a speed of 15¼ knots. By supercharging the engines the normal power may be increased 35 percent. Bow and stern rudders are provided. The "Nyborg" is shown in Fig. 14, with a view of the car deck in Fig. 15.

Above the main or track deck is a promenade deck 210 ft. long, with accommodations for 1,500 passengers. This deck covers the track deck, except for about 72 ft. at the bow and 42 ft. at the stern. Above it is the boat deck. The cars are moved on and off at the bow, where the three tracks unite in one to connect with the single-track

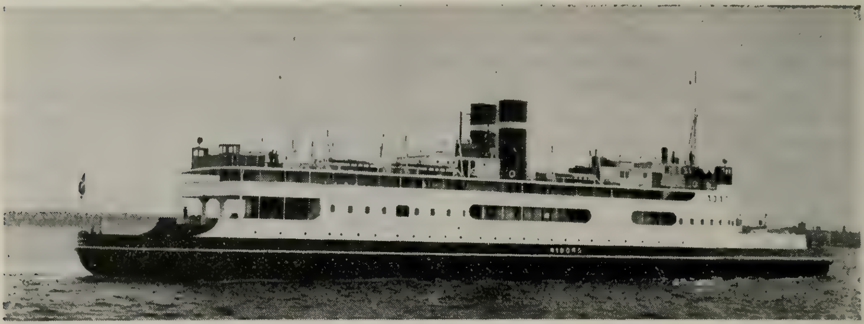


Fig. 14.—Car-Ferry "Nyborg"; Danish State Railways.

landing bridges. Casings or enclosures between the tracks carry the ventilators and engine exhaust pipes leading to funnels of the ordinary type.

Landing connections are made by a bridge hinged at the shore end and having its outer end suspended from a portal truss by cables which pass around drums or sheaves. In this way the end of the bridge can be raised or lowered so as to rest on the deck of the boat.

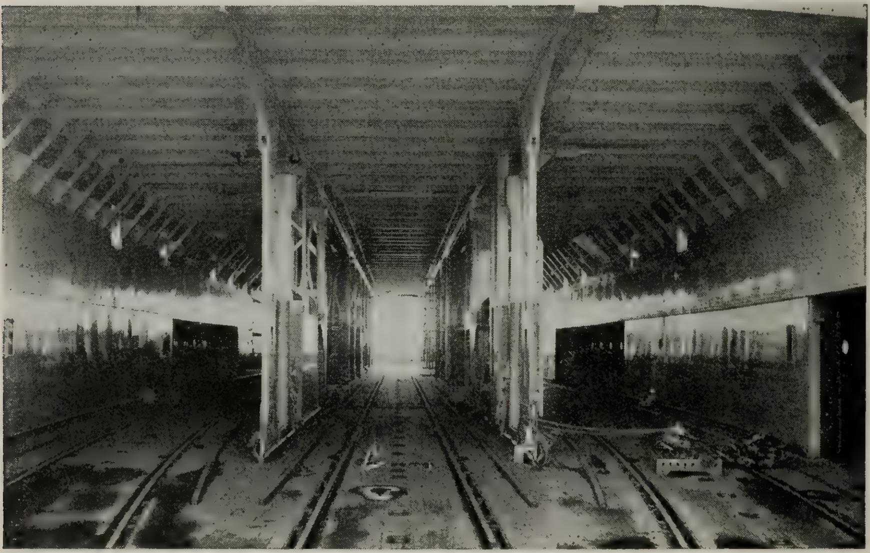


Fig. 15.—Car Deck of "Nyborg"; Danish State Railways.

A third and somewhat smaller car-ferry boat for the crossing of the Great Belt is the "Korsor", 315 ft. long and 68 ft. wide over all, with a draft of 13 ft. Its upper deck extends back 200 ft. from the bow. For trimming the ship and adjusting the list due to various loadings of the cars, there are main trimming tanks having a total capacity of 400 tons, and wing tanks for 160 tons, the shifting of water ballast in the tanks being effected by an electrically operated centrifugal pump. Twin screws are driven by two 8-cylinder oil engines of 4,000 ind. hp. at 180 r.p.m. Landing connections at each terminal consist of an apron or bridge hinged at the shore end and having its outer end suspended from a portal truss by cables leading to motor-driven drums or sheaves. In this way the end of the bridge can be raised or lowered so as to rest on the deck of the boat. The time of crossing is about 1½ hours.

Sweden's Railway Car-Ferries

The Swedish State Railways operate three car ferry routes: Tralleborg-Sassnitz (Germany), Malmo-Copenhagen (Denmark) and Halsingborg-Helsingor (Denmark). The first—and longest—of these is 66 miles. Although there is no tide in the Baltic, there is a difference of 6.56 ft. between the lowest and highest water level at Tralleborg. Most of the passengers are those in the railway cars; others enter the ships by gangways in the usual manner.

Of the four car-ferry steamers on the Tralleborg-Sassnitz route, the two largest are the "Drottnung Victoria" and the "Konung Gustaf V", built respectively in 1909 at Newcastle, England, and in 1910 at Goteborg, Sweden. The latter is shown in Fig. 16.

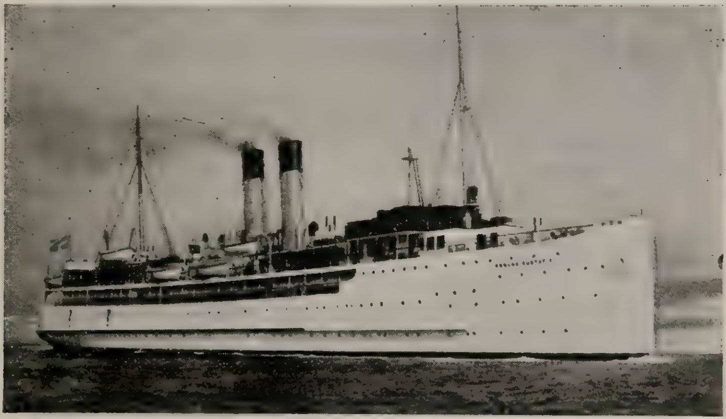


Fig. 16.—Car-Ferry Steamer "Konung Gustaf V"; Swedish State Railways.

They are of 3,300 tons; 370 ft. long, and 54 ft. beam, with a loaded draft of 16 ft. 6 in., equipped with twin screws and steam engines of 5,800 hp. for a speed of 17 miles per hour. Trimming tanks and bilge keels are provided for steadiness in rough weather, but these boats are not built for ice breaking. Two tracks have an aggregate length of 520 ft. In appearance, the ships look much like ocean liners, except for the stern being open above the level of the main or track deck, as in the American car-ferry boats on the Great Lakes. Dining and smoking rooms and saloons are on the upper deck, but passenger cabins or staterooms are below the main deck. The other two boats on this route are somewhat smaller but of generally similar design, and are operated by the German State Railways.

For ice-breaking service on the Tralleborg-Sassnitz route the steamer "Starke" was built in 1931 at Goteborg. It is 305 ft. long, 54 ft. beam, of 2,460 tons, and with twin-screw engines of 5,500 hp. for a sea speed of 13½ knots. Three tracks on the main deck have a total length of 720 ft. In the "Starke," as in some other of these boats, the side plating extends up to the level of the upper deck only from the bow to the bridge, beyond which it is carried up only to about half the height of the car space. In the ice breaking bow, the stem is vertical down to the water line, and then slopes back almost horizontally for a short distance, beyond which it drops vertically to the keel. The bow rudder is in front of this latter vertical portion of the bow.

On the Malmo-Copenhagen route, the vessels look more like ferry boats, having only the middle part of the track deck covered by a superstructure forming the upper deck, with passenger accommodations. In these boats, the cars are moved on and off at the bow. Special ice-breaker car-ferry steamers are also operated. All the ships have bow rudders. The "Malmo" on this route is 270 ft. long, 53 ft. beam, 11 ft. draft, with twin screws and engines of 1,850 hp. for a speed of 12 knots. Its two tracks total 470 ft. in length. These boats are not built as ice-breakers.

The landing berths are stone piers, faced with timber piling conformed to the shape of the stern of the steamers, and having spring buffers fitted between the fender piling and the masonry. A steel landing bridge, connecting the shore track with the deck of the steamer is hinged at the shore end and supported at an intermediate point, while the outboard end is suspended from an overhead truss or portal frame by power-operated cables. At this end is a heavy steel pin or bolt which drops into a socket on the stern of the steamer and thus maintains the tracks on the bridge and deck in exact alinement.

German Railway Car-Ferries

Two car-ferry routes are operated by the German State Railways Company; one between Sassnitz (Germany) and Tralleborg (Sweden), 66 miles; the other between Warnemunde (Germany) and Gjedser (Denmark), 26 miles. Both of these have been noted already. There are two boats on each route, all of similar design. The "Schwerin", shown in Fig. 17, is 347 ft. long, 52 ft. 6 in. beam, with a loaded draft of 13 ft. 9 in. Twin screws are driven by steam engines.

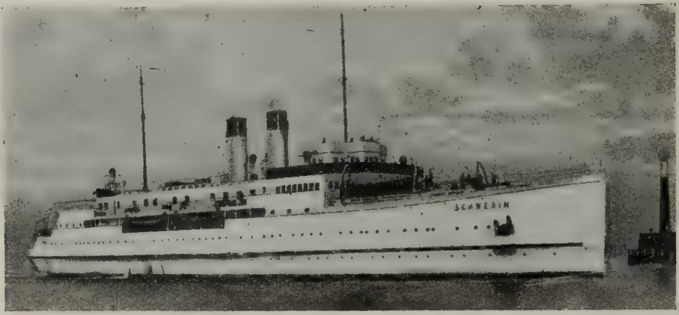


Fig. 17.—Car-Ferry Steamer "Schwerin"; German State Railways.

Lake Constance Car-Ferries

Since 1874 there has been in operation a car-ferry service across Lake Constance, connecting the Swiss Federal Railway system at Romanshorn, with the German State Railways at Friedrichshafen (7½ miles) and Lindau (14½ miles). (See Appendix)

The Zuyder Zee Car-Ferry

For several years the Netherlands State Railways operated a car-ferry across the Zuyder Zee as a short cut. The distance was 15 miles and two boats were in service, but only freight cars were carried. This service was abandoned in 1936, after the construction of levees and drainage works had made dry land of a large area of this arm of the North Sea.

Car-Ferry for the Danube

While the Danube river is crossed by some 30 bridges in its length of 1,770 miles, there is no bridge for a stretch of 390 miles where the river forms the boundary between Roumania and Bulgaria, 246 miles, and Roumania and Jugoslavia, 144 miles. Bridge projects have been planned at various times, but always opposed by the governments concerned for military, strategic and economic reasons, and a consequent purpose to keep their countries isolated to this extent. In 1938, however, the governments of Roumania and Bulgaria agreed to establish a car-ferry to connect their state railway systems and permit of through traffic routing. The service will operate between Giurgiu, on the Roumanian or north side, and Rustchuk on the south or Bulgarian side, from which latter place there is a direct railroad line to the port of Varna, on the Black sea. Work was commenced on the landing facilities, which have to provide for a maximum annual range of 25 ft. in water level.

Two boats are to be provided, one by each country. They will be 214 ft. long, with twin screws driven by oil engines of 350 hp. each. Three tracks will accommodate six passenger cars and six freight cars. Provision will be made for carrying automobiles and other motor vehicles, since important highway routes center at each city. It was intended to have the ferry service in operation in December, 1939. (See Appendix)

Italy's Sicilian Car-Ferry

To connect the railway systems of the mainland and the island of Sicily, the Italian State Railways have maintained since 1899 a car-ferry service across the Strait of Messina, between Messina (Sicily) and Villa San Giovanni, a distance of about 4½ miles. The traffic has increased steadily, reaching 350 to 630 cars daily in 1932, the latter figure being in the fruit export season of Sicily. Both passenger and freight cars are carried. At times the crossing is very rough, so much so that during a storm in 1933 one of the newest boats rolled so heavily that a passenger car was overturned. The crossing is made in 25 to 35 min.

Two large diesel-electric boats put in service in 1931 are of the ferry-boat type in appearance, with a large double-deck superstructure for a length of 200 ft. at the middle of the vessel, giving a headroom of 16 ft. 9 in. above the car deck. The three tracks can accommodate 26 freight cars or 12 passenger cars. These two boats—the "Scilla" and "Cariddi"—are 360 ft. 6 in. long, with a beam of 56 ft. 6 in. and a loaded draft of 12 ft. 6 in. Their gross tonnage is 2,800 tons and displacement 4,050 tons. A view of the "Scilla" is given in Fig. 18. Loading is done at the bow, and to provide for heavy weather, substantial steel doors are fitted to close the car space. These doors, in open position are shown in Fig. 19.

The machinery consists of three 8-cylinder diesel engines driving electric generators which supply current to the two shaft motors of 2,500 hp. each, giving a sea speed of about 15½ miles per hour. The tidal range is only about two feet and at the landings a hinged bridge is adjusted to seat its outer end or the track deck at the bow of the ship.

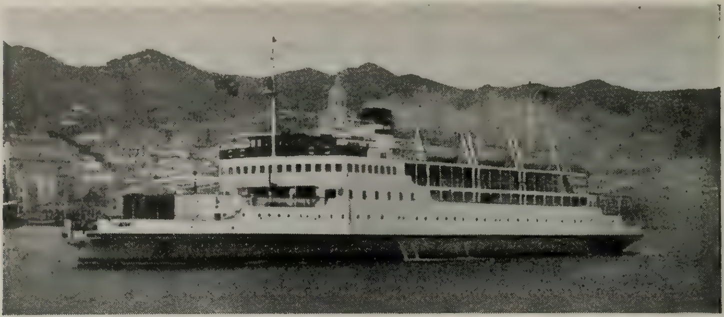


Fig. 18.—Car-Ferry "Scilla"; Italian State Railways.

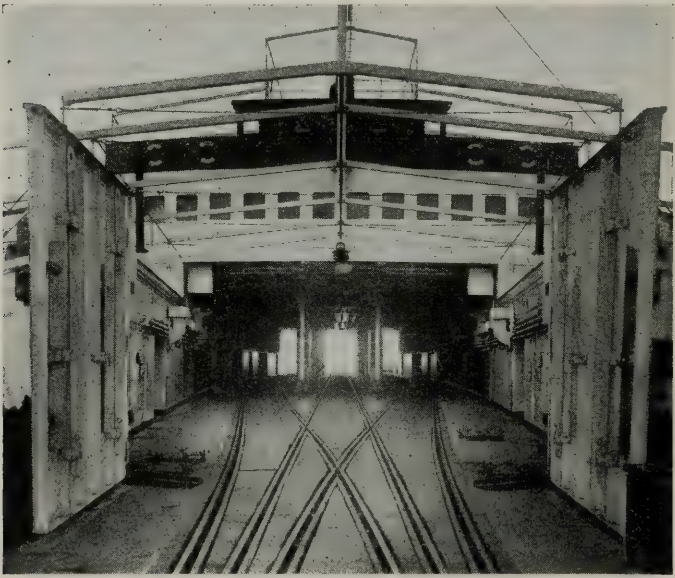


Fig. 19.—Bow of "Scilla", Showing Gates to Close Car Deck.

Russia's Lake Baikal Car-Ferry

When the Trans-Siberian Railway was first built, a difficult section around the south side of Lake Baikal was omitted, and passenger and freight trains were carried across on car-ferry steamers, a distance of 42 miles. During the severe winters, however, tracks were laid on the ice. The Russian Government sent engineers to the United States to study the Lake Michigan car-ferries, and as a result practically duplicates of some of these boats were built in England in 1889. The first was the ice-breaker car-ferry steamer "Baikal", which was shipped "knocked-down" to be re-assembled on Lake Baikal. These ships were 290 ft. long and 57 ft. beam, and each had three sets of triple-expansion engines; two for the twin screws at the stern for propulsion, and the other for a screw in the ice-breaker bow. Some years later, the connecting railway link was built around the south side of the lake and the car-ferry service was abandoned.

River Car-Ferries in Argentina

A very interesting and unusual car-ferry service is that operated by the Entre Rios Railway between Buenos Aires and Ibicuy, a distance of 126 miles. Another ferry runs from Ibicuy to Zarate, 50 miles. The southern terminus of the railway is at Ibicuy, on the Parana river, and the car-ferry service down the Parana and La Plata rivers is operated to give direct connection with the city and port of Buenos Aires. The ferry route from Ibicuy to Zarate, downstream and on the opposite side of the Parana, connects with a line of the Central Argentine Railway from Zarate to Buenos Aires. The longer journey is made in 10 hours and the other in 3¾ hours.

Of the five car-ferry boats, two are driven by steam engines and three by diesel oil engines. The "Carmen de Avellaneda", built in 1931, is 355 ft. 6 in. long, with a beam of 59 ft. 7 in. and a loaded draft of 10 ft. Its four tracks can accommodate 20 passenger cars or 35 long freight cars. Twin screws are driven by two eight-cylinder diesel engines of 2,000 hp. each.

There is a considerable range of water level at the three ports: 24 ft. 8 in. at Buenos Aires, 17 ft. 8 in. at Ibicuy, and 12 ft. 9 in. at Zarate. At each landing a steel transfer bridge 92 ft. long is raised or lowered to approximately the level of the car deck by electrically operated screw gears in a portal girder. A timber apron 30 ft. long extends from the bridge to the deck, where it is secured by four steel locking bolts working in cast-steel guides, at the bow of the car deck. Hoists or winches on the apron assist in drawing the ship's bow into position.

On the Argentine Northeastern Railway, which is operated jointly with the Entre Rios Railway and forms an extension northward, there is a car-ferry across the Parana river from Posadas, the northern terminal, to Pacucua, in the Republic of Paraguay. This crossing is two miles in length and is operated by two sidewheel steamers of 203 ft. 6 in. length, 37 ft. beam, and 4 ft. 6 in. loaded draft. Each boat has two tracks. To accommodate a range of 26 ft. 3 in. in water level, a platform or cradle is raised or lowered on a masonry ramp to adjust it to the position of the ferry steamer. Both the ramp and platform are provided with rails. The passenger and freight cars are raised and lowered on the ramp by a cable and steam hoisting engine.

In connection with the long car-ferry river route of 126 miles, noted above, it is of interest to note that in 1934 the management of the Argentine State Railways proposed to operate a car-ferry from the southern terminal at Santa Fe, on the Parana river, to Buenos Aires, a distance of nearly 300 miles. This would eliminate the transfer of passengers and freight to the competitive Central Argentine Railway for the run from Santa Fe to Buenos Aires. The final outcome was the purchase of the Central Argentine Railway by the State, as an extension of the State Railways to Buenos Aires, so that there was then no need of the ferry.

Burma

A special feature of a car-ferry crossing of the Irrawaddy river, on the Burma Railways, is that the cars are loaded transversely on a ferry barge which is towed by a ferry steamer having passenger accommodations. Originally the ferry crossing was at Sagaing, but this was rendered obsolete by the opening of the Ava Bridge in 1934. The barges, steamers and landing bridges were then moved downstream to another crossing at Henzada. Here the cars are handled by a switch engine, while at Sagaing they were handled on an incline by a cable and hoisting engine. Passenger cars are not carried, the passengers being transferred on the towing steamer. The only exception is for official inspection trains and the Governor's private train, or for passenger cars on the branch line which have to be sent to the shops for repair. The distance is 4½ miles and the crossing is made in about half an hour.

The barges are 190 ft. long and 37 ft. wide in the hull, but the deck width is increased to 45 ft. by projecting guards or sponsons. Their depth is 8 ft. and their loaded draft 3 ft. 8 in. Across the deck are 12 tracks of meter gage, and each track can accommodate two four-wheeled freight cars or one long car on trucks. The maximum dimensions for passenger cars are 47 ft. 6 in. over end sills, or 51 ft. 6 in. over the buffers, and with a wheelbase of 40 ft.

As there is a vertical range of 30 ft. in water level, an inclined track is built down the bank and on this rides a landing bridge whose outer end is supported by a floating landing stage. This bridge is moved up or down the incline according to the water level, its surface being level with the deck of the landing stage, which has several transverse tracks, so that cars can be placed ready for the ferry barge. For loading and unloading, the barge is warped into position by cables and steam hoists or winches on the landing bridge, to bring its tracks in line with those on the landing stage, the barge and stage being then locked together. The native staff was very expert and could unload 24 four-wheeled cars in about half an hour.

Car-Ferries in China

Some of the long lines of China's new railroad system are intersected by the great rivers of that country, but bridging is too expensive to be undertaken at this time. To permit of through rail transportation between Peiping, on the north, and Nanking and Shanghai on the southeast, the Government railway department established a car-ferry in 1934 across the Yangtse-Kiang between the cities of Pukow and Nanking, where the river is about a mile in width.

As the steamers are for river service and do not have to encounter heavy weather or seas, they are of the open-deck type. The two boats were built in England. They are 372 ft. long, and 58 ft. beam, with twin screws, and with bow rudders to facilitate maneuvering. Three standard-gage tracks 300 ft. long are laid on the deck, spaced 12 ft. between centers. They do not converge towards the bow or landing end, as is a more usual arrangement, but are parallel for their entire length to the bow of the ship, where the cars are moved on and off the deck.

A very curious arrangement is the installation of a 42-ft. transfer table across the rear or after end of the tracks on the car deck. This is for the use of a switching engine which is carried on the boat for embarking and disembarking the cars, the engine being thus able to serve all the tracks. When the river is low, the locomotive works at the lower or river end of the incline approaches, pulling trains down onto the boat and pushing them ashore. When the river is at a high stage, the engine works at the upper or shore end of the inclines; pushing trains onto the boat and pulling them off.

To adapt the landings to the changing level of the ship's deck, without requiring heavy grades at a river having a range of 25 ft. in water level, an unusual approach arrangement has been designed. Each landing consists of a bridge with four through-truss spans. The shore end of the first span is hinged, while the adjacent ends of the other spans and the outboard end of the fourth span are suspended adjustably from overhead transverse trusses carried by steel towers on the piers. By this arrangement the spans can be raised or lowered as a unit to give any grade between 3 percent above and 3 percent below the horizontal.

Suspension of the trusses is by means of vertical rods instead of cables, the rods having screw or threaded portions which ride in motor-driven nuts on the overhead structures. For the apron connecting the end span with the ship's deck, the adjustment of level is made by cables operated by motor-driven drums on the overhead truss. At the piers, the ends of adjacent trusses are connected by heavy links, and to these links the vertical lifting rods are attached, so that the four spans are raised or lowered as a unit, to maintain a uniform grade. The last span, however, is kept permanently level, for convenience and safety in the handling of the cars on and off the boat.

The first three spans are 154 ft. long and 20 ft. wide, with a single track. On the fourth span, 152 ft. long, three tracks diverge in fan shape to register with those on the boat. Consequently, the trusses of this span flare outward to give a width of 44 ft. at the outboard end. The floor system of this span extends for only five of the six panels of the trusses. To the floor beam at the fifth panel point is hinged a three-track apron 52 ft. long, extending 26 ft. beyond the end of the span. This apron is suspended near its mid-length by cables, and is adjusted with its end resting on the deck of the steamer. Sliding rails connect the tracks on the apron with those on the deck. For operating the screws which adjust the bridge incline or approach, the motors are of 100 hp. on the outer or river pier, and 85 and 25 hp. on the next two piers, while a 20-hp. motor operates the cables of the apron.

Japan's Car-Ferry System

As Japan, like Denmark, includes a number of islands, the Japanese Government Railways operate three car-ferry lines to provide through train service between the railways of the four principal islands. These railways are all of 3 ft. 6 in. gage. The ferries cross the Tsugaru Strait between Hakodate and Aomori, 70 miles; cross the Inland Sea between Uno and Takamatsu, 12½ miles, and cross the Shimonoseki Strait between Shimonoseki and Komaru, 3 miles.

On the longest line, opened in 1926, there are four steamers, the design of which is in general similar to those on Lake Michigan in having the sides carried up to an upper deck covering practically the entire length of the train deck, while the stern is left open for moving the cars on and off the boat. These Japanese boats, however, have a much larger passenger capacity than most of the American boats of this type, as they have accommodation for about 40 first-class, 200 second-class and 700 third-class passengers.

The steamers are 360 ft. long, 52 ft. beam and 22 ft. deep below the car deck, with a loaded draft of 15 ft. Their displacement is about 4,250 tons. Steam turbines drive twin screws 11 ft. in diameter and 13 ft. 6 in. pitch. Six water-tube boilers serve the turbines. With a speed of about 17 miles an hour the trip is made in about 4½ hours. These boats were built by the Mitsubishi Shipbuilding Company.

On the train deck there are three parallel tracks of the gage of 3 ft. 6 in., all extending to the stern, where the outer tracks begin to converge. The middle track, however, extends forward for only about half the length of the deck, being stopped at the trunk enclosure above the engineroom. They have an aggregate length of 675 ft., sufficient to accommodate 25 freight cars of 15 tons capacity. Ballast tanks in the double bottom are divided into small compartments, so that water can be pumped in or out as required to maintain a uniform draft. Two wing or trimming tanks of 140 tons capacity each, with special pumping equipment, provide for correcting any list or heeling of the boat due to unequal distribution of the cargo load. The pumps are of sufficient capacity to transfer the entire quantity from one side of the hull to the other in four minutes.

At the landings for the long ferry line, a lead track from the yards opens into three parallel tracks to connect with those on the steamer. An 80-ft. girder span is hinged at the shore end, and has its outboard end suspended from an overhead frame by means of hanger bars having the upper ends threaded as screws and passing through motor-driven nuts on the overhead frame. The operating mechanism is driven by a 50-hp. motor mounted on this frame. These vertical screws are connected to the ends of the floor beams by eyebars.

The 108-ton weight of the span is balanced by counterweights on cables which are attached to the ends of the girders and pass over sheaves at the sides of the gantry frame. A 20-ft. apron hinged to the end of the span is arranged to rest on the deck of the boat. This arrangement is similar to that of the English and Chinese car-ferries already described, and with it the ship's tracks are not extended to the extreme end of the deck.

At Hakodate, there are berths for two boats alongside the mole or quay, which extends as far as the railway station yard. For the convenience of passengers, covered walks extend from each berth to the waiting-room on the quay, connecting the second story of the building with the upper deck of the boat, on which the passenger facilities are arranged. This quay has walls of hollow concrete caissons sunk in place on a bed of loose rock and then filled with sand, except that an interior wall of concrete is filled against the outer or water side of the caisson. Upon each of these rows of caissons is a superstructure or dock wall of mass concrete, and the space between the two lines of caissons is filled with sand. At Aomori, the quay walls are built partly of hollow concrete caissons, and partly of solid concrete blocks laid up like masonry, each construction being capped with a mass concrete wall.

It is interesting to note that on account of the heavy traffic across the Shimonoseki straits and the rough seas frequently encountered, the Imperial Government Railway Department has built a tunnel under the straits. This tunnel is about five miles long, with three miles under the water.

Part IV.—Car-Ferry Landings

Adequate landing facilities for the steamers and terminal facilities for the trains are essential features of the rail-and-water terminals of a car-ferry line. This is especially important where at busy times it may be necessary to unload and reload the boats as quickly as possible, which is frequently the case on the Lake Michigan lines. There must be slips or berths for the boats, and yard tracks for the trains and the handling of cars, together with the necessary connections between the shore tracks and the tracks on the deck of the steamer. These landing or track connections between ship and shore must provide, of course, for the tidal or other changes in water level, and in almost every case this adjustment is made by the shore equipment. In the very exceptional case of a former Canadian railway car-ferry at Quebec, the change in level of the track connections was provided for on the boat instead of at the landings. This was effected, as has been described, by having a movable deck, which (with its load) could be raised and lowered through a distance of nearly 20 ft. This special system was, in its way, as novel a feature as the more recent "Seatrain" system of carrying cars on several decks of the steamer and handling them through deck hatches by means of overhead cranes.

The landing facilities for car-ferry lines are provided usually by the railways, as integral parts of their terminals. At some ports, however, they are provided by the municipal or port authorities, or by some local interests. At Milwaukee, for instance, a municipal terminal for car-ferry vessels is a part of the harbor facilities. It includes two slips for the boats, and trackage connecting with the trunk lines that enter the city. A five-track boat yard adjacent to the slips serves for placing cars ready for transfer to the boat and for receiving cars as they are pulled from the boat. A 12-track classification yard serves for arranging the inbound and outbound cars in required order.

Switching of the cars at this terminal is handled by the railroads, which lease the facilities from the Milwaukee Harbor Board. This terminal supplements the individual or private landings of the Pere Marquette Railroad and the Grand Trunk Western Railway. At Muskegon, Mich., the arrangement is different, a car-ferry terminal having been built in 1933 by a local concern, the Muskegon Railway & Navigation Company, as an inducement for the Grand Trunk Western Railway to leave Grand Haven and adopt Muskegon as the eastern terminal or port of its Milwaukee car-ferry service.

Ample space and adequate facilities for rapid and easy turning of the boats at the landing are also essential, since in most cases the arriving boat must turn and back into the slip or landing. When finally moored in position, the boat must be held in exact line with the approach, so that its rails will register with those of the shore tracks. The deck and shore tracks must also meet at the same level, and there must be no wide gap in the rail connections. Passengers, other than those in the cars, may enter and leave the boat by way of the train deck. But at some landings there is a tower with stairs and a movable gang-plank enabling passengers to go directly to and from the upper deck, on which the passenger accommodations are arranged. At some foreign terminals, covered elevated walks are built across the tracks to connect upper-story waiting rooms with the upper decks of the steamers.

Car-Ferry Slips and Berths

For docking the car-ferry boats, the usual arrangement is to have two lines of timber fender piling to form a slip or berth, the inner or land end of which is shaped to fit the outline of the ship's stern and so hold it steadily and prevent lateral motion. The two lines of piling flare outward, so as to guide the ship easily into its position, but while one line is practically the full length of the slip, the other—known as the "knuckle"—is much shorter. As noted already, the boats usually back into the slip for loading and unloading over the stern; alternative methods, used only to a limited extent, are for loading and unloading over the bow, or at either bow or stern with double-end boats. An occasional modification of the fender design is to have a series of pile clusters instead of a continuous line of pile fendering to form the outer part of the longer line of the slip. Such pile clusters are shown in Fig. 11. Heavy iron-plated fenders along the ship's sides take the shock and wear of engaging the landing. The ship is moored also by stern lines in the usual way.

MILWAUKEE MUNICIPAL CAR-FERRY TERMINAL.—Typical of car-ferry slips is that of the Milwaukee municipal terminal, already mentioned. Here the boat lies between the two fenders, one nearly as long as the ship and the other only long enough to hold the stern in position. Fender construction consists of three rows of wood piles, with laminated wales between them and on both sides. To the inner wales is attached a facing of 6 by 8-in. vertical timbers, with a steel rail in every third joint, the rail heads projecting ½-in. beyond the timbers. At the outer end of the longer fender is a protective dolphin or cluster of 81 piles, tightly wrapped with steel cable.

About 80 ft. beyond the dolphin is a reinforced-concrete pier of approximately 30 ft. diameter, around which the boats swing when turning to back into the slip. It is a hollow caisson, 17 ft. high, with a 54-in. bottom slab encasing the heads of the foundation piles, and an 8-in. top or deck slab, with snubbing post for the ship's turning cable. To withstand the heavy pressure of the ship against the pier while turning, the interior is divided by partition walls. A plan of this marine terminal is given in Fig. 20. Furthermore, to protect the concrete from injury, the pier is faced in the same way as the fenders, the vertical timbers being fastened to 8 by 12-in. creosoted wales secured to the concrete by vertical bolts in projecting anchor bars on which the wales are seated.

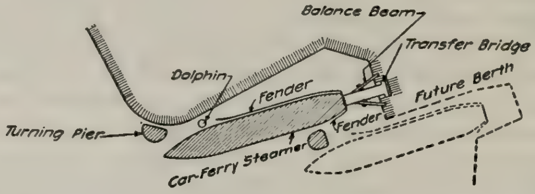


Fig. 20.—Municipal Car-Ferry Landing at Milwaukee, Wis.

Great Lakes Car-Ferry Landings

Although there are no tides on the Great Lakes, the water level varies seasonally and is affected by the winds, the maximum variation on Lake Michigan being about eight feet over a long term of years. Furthermore, the draft of the steamers varies with their loads, and at the landing they may take a list or lateral tilt owing to changes in the distribution of the load as cars are pushed on or pulled off the deck tracks. For the adjustment of level between the rails on deck and those on shore, there is a steel bridge span, 50 to 85 ft. long, composed of longitudinal deck girders, with bracing between them. The span is hinged on the abutment at the shore end. Its outboard end is supported by hanger rods which are attached to the ends of a long cross girder of the span and to the ends of two horizontal pivoted balance or rocking beams, from the rear ends of which are suspended counterweights to balance the weight of the span. A geared winch or hoist, operated by hand or by power, has cables attached to the rear ends of the rocking beams, and by these means the beams can be tilted to raise or lower the outboard end of the span or apron as desired.

A car-ferry landing of this type, illustrated in Fig. 21, is that of the Pere Marquette Railroad at Ludington, Mich.; built for the use of the new turbo-electric steamers which have been described. Here the double-track span consists of five parallel plate girders 80 ft. 6 in. long, hinged or pivoted at the abutment end and connected by bracing, somewhat as in an ordinary bridge span. A cross girder framed between the webs is extended beyond the outer girders for the attachment of hangers suspended from the shorter arms of a pair of 60-ft. balance beams. Each beam is mounted on a high steel tower and has a counterweight hanging from its longer arm.

Although the transfer bridge may receive violent shocks and hard usage occasionally, with blows direct or eccentric as the stern of the incoming boat engages it, the connection is made usually with relatively little shock. In some of the earlier landings, buffer springs were placed between the rear of the span and the abutment, to take up the shocks. At present, more reliance is placed on sufficient strength of construction to resist these buffing shocks. However, it is also usual to provide anchors or hold-downs at the pivots of the girders, so that a severe end shock will not cause the shore end to lift from its bearings.

The fender piles extend 10 to 12 ft. above the water and are connected by walings usually built up of planks, this laminated construction being more flexible than solid timber wales of the same cross-section. To the wales on the berth side of the fender, plank sheathing may be attached to distribute the shocks and take the abrasion from the ship's fenders. With the long piles and the built-up waling, the fender can give or yield as the ship strikes it or bears heavily against it in coming into the berth, the fender then returning to its normal position when the pressure is released. There is usually a fender only 40 to 60 ft. long on one side of the slip, while on the other side the fender is somewhat longer than the ship and is protected at its outer end by a cluster of piles wrapped with steel cable. This general arrangement is shown in Fig. 20, and a typical construction of such fenders is shown in Fig. 22.

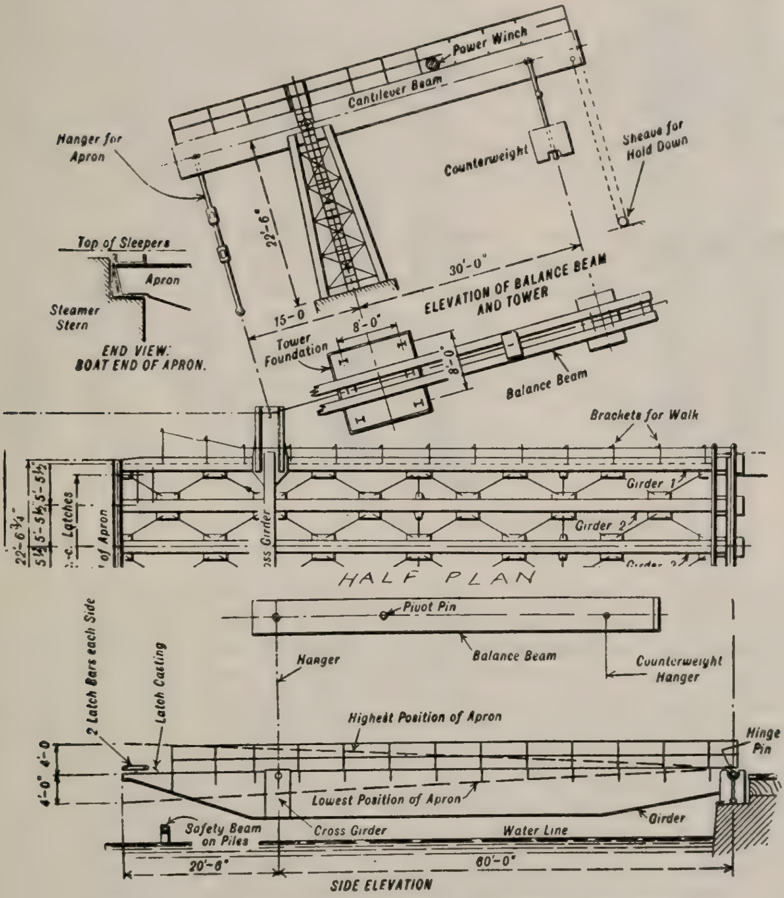


Fig. 21.—Car-Ferry Landing Bridge at Ludington, Michigan: Pere Marquette Railway.

Dock for Channel Car-Ferry

An exceptional feature of the Channel car-ferry between England and France, already described, is that the terminal at Dover, England, built by the Southern Rail-

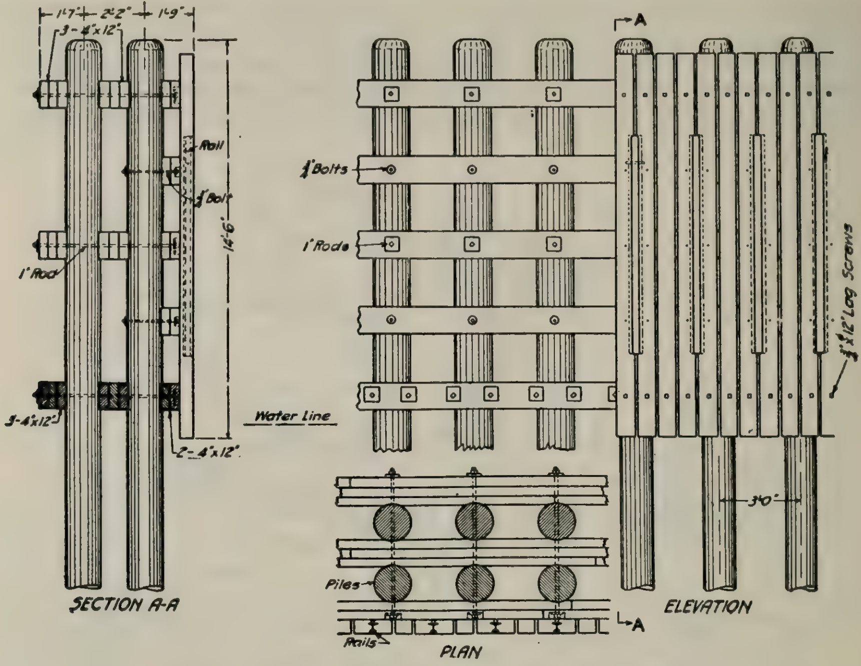


Fig. 22.—Fender Construction for Car-Ferry Landings.

way—which operates the ferry—consists of a closed dock. Here a tidal range of 23 ft., and a location in an outer harbor protected only by a breakwater, precluded the use of a harbor slip and landing in open water, connected with the shore by a simple hinged apron span. It was decided therefore, to build a closed dock of such size as to accommodate one ferry steamer, the water level to be raised or lowered by pumping, as required. This dock is 416 ft. long, 60 to 72 ft. wide and 45.72 ft. deep, with 17 ft. of water on the sill at lowest tide, giving 3 ft. of water under the ship's keel. The inner or land end of the dock is shaped to the contour of the ship's stern and is faced with timber fendering. There is no entrance lock, a single gate separating the dock from the harbor, but for reserve or emergency use there is a duplicate gate 20 ft. in advance. Each gate is a hollow steel caisson with bearings at the bottom, so that it lies flat on the floor when the dock is open. Pumping equipment to regulate the water level consists of three centrifugal pumps driven by 230-hp. motors and having an aggregate capacity of 120,000 gal. per min.

To connect the shore tracks with those on the steamer, there is an adjustable landing bridge consisting of a double-track 70-ft., 140-ton, shallow through-truss span pivoted at its shore bearings, and so counterweighted that a weight of only 12 tons is carried by the ship. Its outboard end has pins attached to a pair of eyebar suspenders, the upper end of each bar carrying a sheave which rides in the bight or loop of a hoisting cable. One end of each cable is anchored to the overhead span of a steel portal structure spanning the inner end of the dock, while the other end is wrapped around a motor-driven hoist on this structure. To provide for lateral heeling of the ship due to varying loads, the floor framing of this bridge is made flexible, the floor beams having spherical end bearings in the trusses. This permits a drop of 30 in. at either end, or a heel of 5 deg., without imposing warping stresses in the trusses. When the end of the span is seated on the ship, a socket on the end floor beam engages a vertical pin in the deck and is secured by a locking bolt through a slot in the pin. The span is then disconnected from the hoisting machinery and is free to follow any swing or heel of the ship. Drop rails hinged to the track rails on the span fit into sockets and make scarf joints with the deck rails.

One side of the dock is extended 400 ft. into the harbor to form a jetty which consists of concrete piers 11 ft. apart, connected by struts and carrying an 18-in. deck slab 30 ft. wide, reinforced with I-beams under the track rails. Timber fendering on the piers is backed by spring buffers in cast-steel boxes anchored to the faces of the piers. Each buffer has three concentric springs, and provides for a compression or travel of 3 in. under a pressure of 70 tons. The pockets are filled with grease to prevent corrosion.

For the Channel car-ferry terminal at Dunkerque, France, no special dock is required, since this large port consists of a closed or floating harbor entered through locks. Thus a permanent or uniform water level is maintained in all the docks or basins, in spite of a daily tidal range of 21 ft. The depth of water on the lock sills of the entrance locks is sufficient to allow steamers to enter at the lowest tide. The car-ferry steamer is berthed along a quay, its stern being held in position by the usual type of concave fendering and connected with the land tracks on the quay. Passengers enter and leave by a side gangway at the upper deck level, a ramp connecting with the customs offices and with the railway station at the ground level. Connection with the shore tracks is effected by a two-span landing bridge, which is described later.

Adjustable Landing Connections

From the preceding descriptions of various car-ferries here and abroad it will be noted that there are four distinct types of facilities for transferring cars between the shore tracks and the ship's tracks. First, a hinged apron or span. Second, a series of two to six spans operated as a unit structure hinged at the shore end, and adjustable to grade and elevation. Third, a cradle with a track on its deck and traveling on an inclined track. Fourth, a cantilever crane or traveling crane. The first is the most general, consisting of a plate-girder span, 60 to 100 ft. long. Its shore end is hinged, and its outer end is suspended in such a way as to permit of raising or lowering it to the level of the ship's deck, according to the varying water level and the varying freeboard of the ship with light or heavy cargo of cars. The second is a development for greater length. The traveling cradle system is used at river ports where the banks are flat and the water has a large and frequently changing stage. The crane system is used with ships for which the cars are handled through deck hatches and are carried on several decks. Such vessels are used only where speed of embarking and disembarking is not an important consideration, the cars being transported in large numbers and at long intervals. A curious alternative is to provide several decks on the ferry vessel and use whichever is nearest the shore level, as in the Belgian vessel noted in the appendix.

For the suspension and operation of the outboard ends of the landing aprons of the first two types mentioned above, there are five different methods: (1) Hanger rods from rocking beams; (2) counterweighted cables; (3) hanger rods having threaded portions which ride in power-driven nuts on an overhead span; (4) hoisting tackle from power-operated drums on an overhead span, a hoist to each side of the apron; (5) a single power hoist similarly mounted, with tackle carrying a transverse beam whose ends are attached to the apron girders by hangers. All but the last method have duplicate equipment for each side of the apron, and this last is the only one using a single hoist.

Single-Span Transfer Bridges

In the usual design of the simple landing apron or transfer bridge for a car-ferry, there is a series of parallel deck-plate girders connected by laterals and sway bracing, and having near the outboard end a transverse truss or girder framed between their webs and projecting far enough on each side for the attachment of the hangers or suspension cables, as above described. At the shore end, each girder has a pin, trunnion or rocker bearing, so that the apron can be swung up or down, its outboard end having sufficient vertical travel for the maximum difference in elevation between ship and shore.

In addition to the ordinary loading of cars, the apron is subject to severe warping or twisting strains, since its outboard end is locked to the deck of the ship, which has a variable lateral movement as the ship lists to one side or the other, due to the shifting of cargo loads as the cars are moved on and off the deck. In some cases, the end of the apron is made with projections or serrations to engage corresponding indentations in the stern of the boat. This arrangement holds the boat and apron rigidly in line, but does not affect the variations from horizontal.

As a rule, the apron is designed to be laterally stiff, with strong connections between the girders and the cross-bracing. But in a 75-ft. apron built in 1927 for the Grand Trunk Western Railway car-ferry landing at Milwaukee, the opposite method was employed, and the structure made laterally flexible. All sway bracing was omitted, while the top and bottom laterals were connected to brackets on the girders by horizontal pins, so that the girders could move independently in a vertical direction. Where these girders passed through the web of the transverse lifting girder, which was 14 ft. 6 in. back from the outboard end of the apron, they were seated on curved or convex bearing plates to provide for a lateral rocking movement. Thus the outboard end of the apron had a vertical adjustment of 6 ft. for the deck level, and a lateral movement of 1 ft. difference in elevation between the two sides. Flexible floor framing is used also in the car-ferry landing bridges at Dover (England), Dunkerque (France), and Larne (Ireland), as noted.

For the adjustment of the apron, its outboard end may be suspended by cables or hangers attached to an overhead truss or girder spanning the ferry slip, or to a pair of balanced rocking beams, one on each side of the slip. The cables may be operated by direct hoisting or may carry counterweights. The rocking beams are counterweighted and are operated by power or hand gearing so as to adjust the level of the end of the apron to the level of the ship's deck. In most cases they are at an angle with the center line of the tracks, in order to carry the counterweights clear of the apron.

Typical of such landing aprons is that of the municipal car-ferry landing at Milwaukee. It is 80 ft. 6 in. in length, composed of five deck plate-girders hinged by trunnion bearings at the shore end. At 20 ft. 6 in. from the outboard end is a transverse girder framed between the girder webs and extended on each side for the attachment of a suspender bar or hanger. The deck is of 6 by 8-in. ties, 2 in. apart, covered with a floor of 3 by 12-in. treated planks laid diagonally, and a wearing surface of similar but untreated planks laid transversely. Two tracks entering the rear or heel of the apron diverge to four tracks to register with those on the boat. Each of the suspenders is attached to the end of a rocking beam 25 ft. long, pivoted to form a 10-ft. arm carrying the suspender and a 15-ft. counterweighted arm.

At each side of the slip is a steel tower about 30 ft. high, carrying the bearings for a pivoted horizontal rocking beam 54 ft. 8 in. long, composed of a pair of 54-in. girders. The short arm of the beam, about 21 ft., carries the suspender attached to the cross-girder of the apron, while from the longer arm is suspended a counterweight in the form of about 26 tons of cast-iron slabs. To raise and lower the outboard end of the apron, a cable anchored to the dock structure is led over guide sheaves and up to a motor-operated drum mounted on the beam. By hauling on the cable, the rear of the beam is pulled down, thus raising the apron. When the cable is paid out, the excess weight of the apron pulls the beams down. An auxiliary device is provided in the form of a chain hooked to the rear end of the beam and led down and along the dock to a hand hoist.

There are, of course, many variations in the design and operating mechanism of these landing aprons. At the landings of the Detroit River car-ferry of the Wabash Railroad, for instance, the rocking beams are parallel with, instead of at an angle to, the center line of the apron. Of greater importance is the omission of the usual tall towers to support the rocking beams. Instead, simple braced columns or pedestals carry the trunnion bearings about 9 ft. above the water or 5 ft. above the track. The beams are 25 ft. 6 in. long, pivoted at 7 ft. from the end carrying the hangers. For operation, a chain attached to the rear end of the beam passes down and is led to a drum operated by hand or power gearing. In Fig. 23 is shown one of the rocking balance beams of this landing, with its suspender bar attached to the end of a cross-girder near the end of the apron span.

To lock the end of the apron rigidly to the deck of the boat, two of the girders have each a pivoted eyebar carrying a heavy latch bar which is slotted to drop over a lug on the deck. Loose filler blocks are fitted into the slot for adjustment of its length. In other designs, the slotted latch or lock is pivoted to the end of a threaded bar working in a horizontal casting on the apron. When the bar is dropped over the

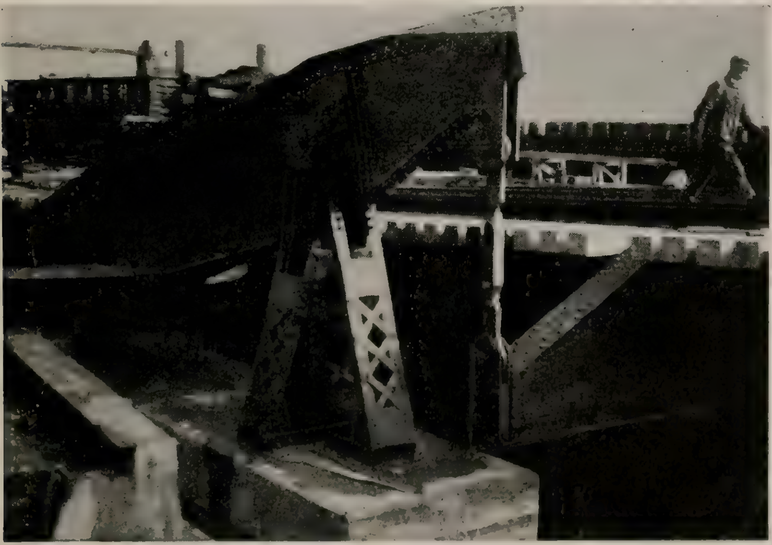


Fig. 23.—Car-Ferry Balanced Landing Bridge; Wabash Railway.

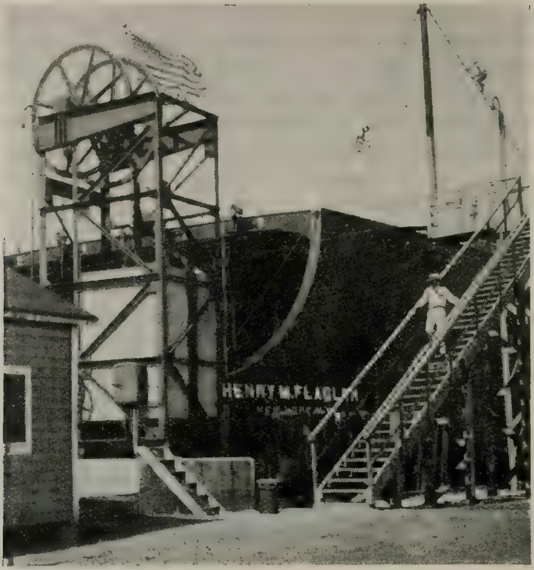


Fig. 24.—Car-Ferry Landing; Florida East Coast Railway.

deck lug, the screw is turned to draw the connection tight. For the car-floats in New York Harbor, mentioned previously, a common arrangement was a cast-steel latch bar about 7 in. square and 7 ft. long, sliding in pockets fastened to the apron floor and the boat deck.

To reduce the rail gap at the heel of the apron, the approach rails are sometimes extended about a foot onto the apron, where their ends rest upon convex base plates. One side of the rail head on the approach and the apron is planed away, and a cast-steel bar with curved top surface is bolted to the web of the approach rail and lies against the web of the apron rail. This bar carries the wheels across the gap. A timber beam across the slip, under the apron and supported at the ends on piles, prevents the apron from dropping below a prescribed position.

While the rocking-beam arrangement is the more general, a counterweighted cable system is used at Port Everglades, Fla., the terminal of the Cuban car-ferry line of the Florida East Coast Railway. Here the 60-ft. apron is of the usual type, with ten lines of fish-belly plate-girders connected by transverse trusses and having near the outboard end a pair of cross girders framed between the girder webs and extending on either side. On a foundation pier at each side of the slip is a steel tower 21 ft. high, carrying a shaft with a pair of 8-ft. grooved sheaves. Over each sheave passes a 1⅝-in. steel cable, having one end attached to the transverse lifting girder of the apron, and the other end attached to a counterweight sliding within the tower. Both cables are attached to the same counterweight.

Raising and lowering of the apron is effected by a third cable on each side, ¾-in. in diameter. This is attached to a diaphragm between the ends of the double or twin lifting girder and passes over a guide sheave to a drum on the tower, operated through gearing from a hand-wheel. A view of one of these counterweight towers, with its large sheaves, is shown in Fig. 24, which also shows the stern of the car-ferry steamer "Henry M. Flagler" moored in the slip.

New York Central Railroad.—Through-truss timber spans and through-girder spans have been employed for many of the car-ferry boat or float landings of railways terminating in New York Harbor, which have been described previously. In some of the older timber structures of the New York Central Railroad the trusses were 70 ft. long and 10 ft. deep, counterbalanced by weights on cables passing over sheaves on a gallows frame. An apron 25 ft. long took the torsional or twisting stresses due to lateral listing of the barges or floats, as damage was too severe and maintenance costs too heavy with the bridge itself latched rigidly to the deck. The position of the apron was adjusted by counterweights and cables led to a winding drum. For adjustment of the level of the bridge, its outboard end was suspended by hanger rods having threaded portions forming vertical screws and passing through nuts mounted on the gallows frame. These nuts were revolved by power through worm gears. Some old landings had the outboard end of the bridge seated on a pontoon, rising and falling with the water level. But ice troubles made this arrangement unsatisfactory, and as the weights of loaded cars increased, the pontoon support was gradually abandoned. The tidal range is about 12 ft.

At a double-track landing built in 1911 for the New York Central Railroad, each track had a plate-girder span 110 ft. long, but 80 ft. to the hinged heel of a 30-ft. apron which did not extend beyond the ends of the girders. At 20-ft. from the outboard end of each girder was attached a hanger rod with threaded screw, as above described, the train of worm gears being driven by a 50-hp. motor. With a vertical range of 16 ft. for the elevation of the outboard end, the maximum grade on the landing span was 8 per cent above or below the horizontal, but the normal maximum was only 5 per cent. At the end of the apron the rails were not spiked, and could be shifted laterally by horizontal screw jacks, so as to register with the rails on the deck of the car-float.

New York, New Haven & Hartford Railroad.—Notable landings of this type are those of the New York, New Haven & Hartford Railroad, at its Oak Point terminal yard on the Harlem river, at New York. There are a number of these landings, arranged side by side, and each consists of a 100-ft. through-girder span or "float bridge" with three plate girders, and having hinged to its outboard end a 30-ft. deck-span apron. One of these landings, with its operating and counterweighting equipment, is shown in Fig. 25. Under the shore end of the girder span is a rocking-log hinge, consisting of a timber with semicircular face seated in a concave bearing. At its outboard end, this span is suspended from an overhead steel structure by hangers attached to vertical screws. The hanger of the middle girder has a yoke attached to a pair of screws.

These operating screws pass through motor-driven nuts on the ovehead structure, by which means the end of the bridge is raised and lowered. Just behind the hangers are cables which are attached to the bridge girders and pass over sheaves in the overhead structure, their other ends carrying counterweights. Thus the screws have to lift only the excess weight of the bridge.

The 30-ft. apron, hinged to the end of the girder span, has its outboard end suspended from another overhead steel structure by three sets of cables at each side. One set of cables passes down to a motor-driven operating drum; the others carry separate counterweights for dead and live load.

In operation, after adjusting the track alignment to meet the ends of the rails on the car-float, the float-bridge is raised or lowered, as may be necessary. Then the bridge

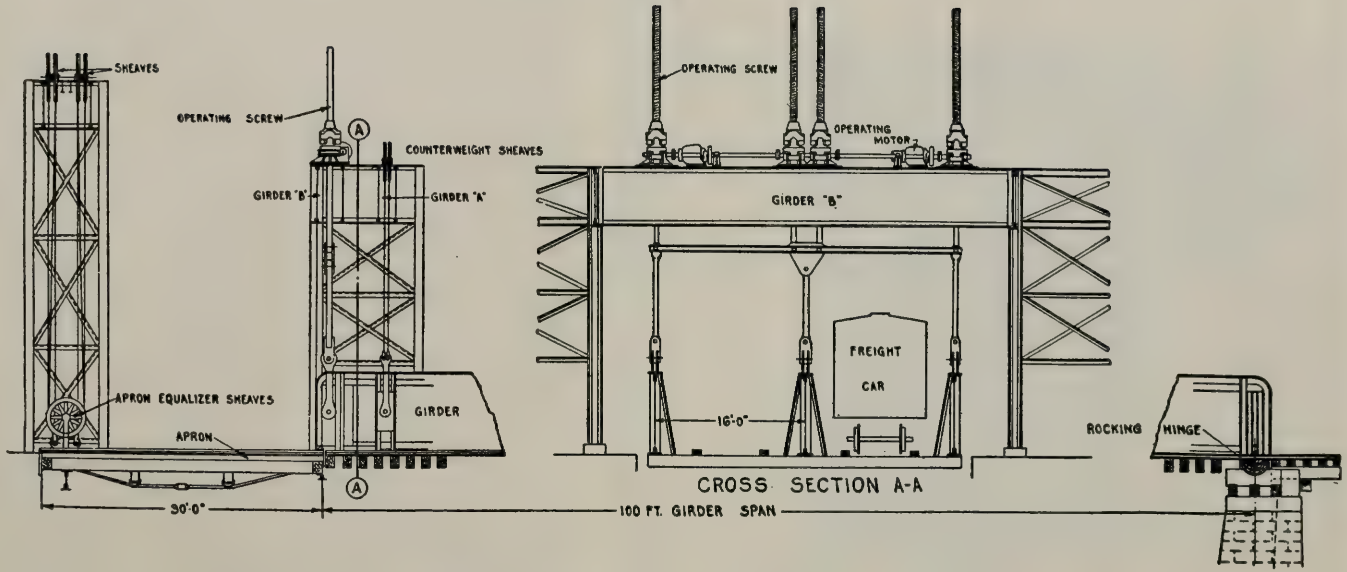


Fig. 25.—Car-Ferry Landings; New York, New Haven & Hartford Railroad.

apron is likewise raised or lowered, and the ends of its rails are lined up with the ends of the rails on the car-float, and held in place by means of heavy toggle pins slipped through toggles on the end of the apron and float. When the float is made fast, the strain on the cables at the end of the bridge span is held; but the cables on the end of the apron are slacked away, so that the end of the apron rides freely on the end of the car-float. It can thus follow the rise and fall of the float as cars are pulled from or loaded onto the float. The normal change in water level is about six feet.

London & Northeastern Railway.—In the hoisting equipment for adjusting the level of the outboard end of the landing bridge, the usual arrangement is to have the equipment in duplicate on both sides of the bridge, although a single hoist is used in exceptional cases, as already noted. This last-named, single power-hoist arrangement is a conspicuous feature of the landing of the English–Belgian—or Harwich–Zeebrugge—car-ferry of the London & Northeastern Railway at Harwich, England. The construction is rather unusually heavy and substantial, as will be seen from the two photographs reproduced in Figs. 26 and 27. The former is a view from the shore end of the double-track landing bridge, and shows the tower or portal frame which spans the outboard end of the bridge. Beyond it, is one of the car-ferry steamers moored in the berth. At the left is a stairway on the approach to the footwalk which surmounts the timber fender holding the ship in position. In Fig. 27 is shown a side view of the heavy half-through truss span which forms the landing bridge, and which in this view is raised above the deck level of the steamer.

In both views it will be seen that from the lower block of the multiple-part hoisting tackle is suspended a transverse A-frame, from each end of which depends a hanger attached to the truss of the landing bridge. The horizontal member of the frame, of course, is at such a height above the rails as to give ample clearance for the highest cars. Its ends ride in guides in the side columns of the tower.

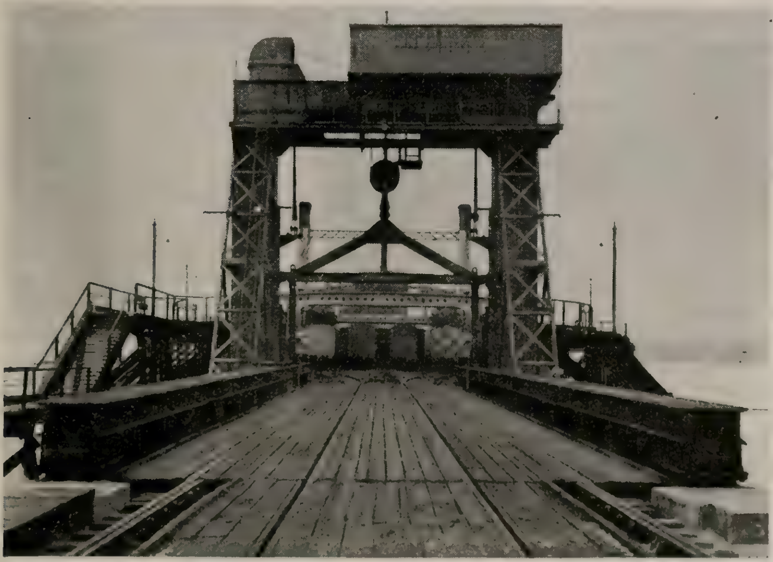


Fig. 26.—Car-Ferry Landing at Harwich, England; London & Northeastern Railway.

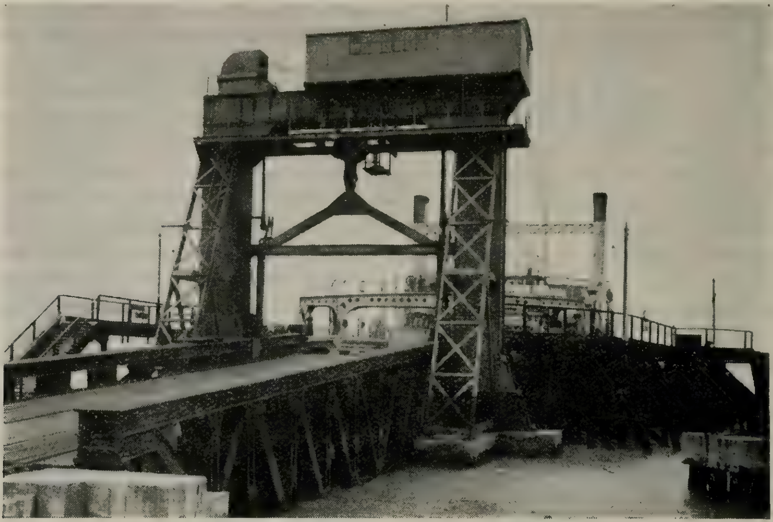


Fig. 27.—Car-Ferry Landing Bridge; London & Northeastern Railway.

Jack-Knife Landing Apron

A flexible landing apron or bridge, which accommodates itself automatically to changes in level due to tide, and in the longitudinal and lateral motion of the ship as cars move on and off the deck, is a special feature of the terminals of the ferry for automobiles operated between Scotland and Ireland by the London, Midland & Scottish Railway. This ferry has been described previously. The apron, 10 ft. wide, is in three sections; the first being a 70-ft. plate girder structure, with pivot bearings under the shore end and having its outboard end (which is in line with the face of the quay wall) suspended by cables from an overhead portal frame. From the head sheaves on this frame, the cables lead down to electric hoists outside the legs of the frame. Hinged to the end of this section is an 11-ft. section having longitudinal I-beams; this is raised and lowered by cables leading back to sheaves on low steel towers in line with the legs of the portal frame and thence down to electric hoists in an underground chamber. This section rests on the ship's deck when lowered. Hinged to this again is a 4-ft. section tapered to give an easy rise from the deck to the apron. To prevent cars from being driven onto the landing apron before it is adjusted, the 4-ft. end section does not reach the deck until after the 11-ft. section has come to a bearing on the deck. The maximum variation in level at the outboard end is 11 ft. (10 ft. for the tide changes and 1 ft. for the ship's movements). This variation is for an elevation from 8 ft. below the level of the quay to 3 ft. above it, with grades of 10 and 20 percent, respectively. The two outer or end sections always have a down grade to the deck. When the landing apron is not in use, the outboard end of the 70-ft. section is seated on shoes, so that its deck forms a part of the surface of the quay and there is no load on the hoisting cables. The two outer sections are raised to an approximately vertical position, and are held against spring buffers on the legs of the portal frame to prevent shaking or vibration due to wind.

Automatic regulation to maintain the landing apron in position on the ship's deck, accommodating itself to all swaying motions, is effected by means of electric switches on a moving frame which control the actions of the cable hoists for any difference of two inches or more. A powerful spring with dashpot device prevents sudden motion such as might be caused by waves. A diagonal hinge at the inner end of the 11-ft. section provides for rolling or lateral list of the vessel. Manual control by push-buttons regulates the operations during raising and lowering of the apron, but automatic regulation is in effect as long as the apron is seated on the ship's deck.

Another interesting detail of the ferry terminal at Larne is that a belt conveyor 200 ft. long, handles the mail sacks between the ship and the railway station. The conveyor has a flexible end section that is adjustable vertically to suit the level of the ship's deck and adjustable laterally to serve various loading points on the ship.

Suspended Multiple-Span Landings

Where the changes in water level are too great to be compensated by the adjustment and inclination of a single span, there may be a series of spans, all adjustable in elevation. All the spans are suspended from an overhead structure and are so connected and operated that they form a unit structure, rotating on bearings at the shore abutment and giving a continuous or uniform grade from the shore end to the outboard end, engaging the deck of the steamer. In this way a longer incline with easier grade is obtained, while in comparison with the trestle incline and traveling cradle system (noted later) the length is much shorter, and tracks and moving parts under water are avoided. This system was used for the New Orleans car-ferry landings of the Southern Pacific Railway and the Texas & Pacific Railway. It has been adopted also at the landings for the car-ferry crossing of the Yangtse-Kiang, on the Peiping-Nankin Railway, in China, and for the landing at Dunkerque (France) for the English-French car-ferry line. Both of these foreign car-ferries and their landings have been described already.

Texas & New Orleans.—For the landings at New Orleans and Algiers, on the Mississippi River car-ferry (abandoned since the completion of the New Orleans bridge), this suspension system was adopted in preference to the incline and cradle system which is used extensively at other points on the river. There were six 45-ft. spans, with an 18-ft. apron extension, and the grade was adjustable within a range of 3 percent ascending and 3½ percent descending towards the river. The girder spans formed a continuous deck, which was pivoted at the shore end and suspended at six points from portal bents or gallows frames by means of hanger bars.

Adjustment of the elevation and grade was effected by having the hangers threaded as screws, and engaged by power-operated nuts on the gallows frames. The hangers were attached to the ends of cross girders upon which the span girders were seated. The screws at each point of suspension were of such pitch that the change of elevation was accomplished, without change in the plane of the track, by rotating the screws with the same number of turns of the operating nuts. An alternative method would be to so vary the gearing at the different suspension points that all the screws might be of the same pitch.

Line shafting for the operation of the several sets of worm gearing at the hangers was carried on longitudinal overhead trusses supported by the gallows frames. The general arrangement of the gearing is shown in Fig. 28, with details of one of the worm-gear sets in Fig. 29. Although the mechanism appears somewhat complicated, there was no serious trouble during its several years of operation. No mechanical adjustment was provided for the apron, the connection being effected automatically by the inclined surface of the boat's bow riding under the projecting end of the apron.

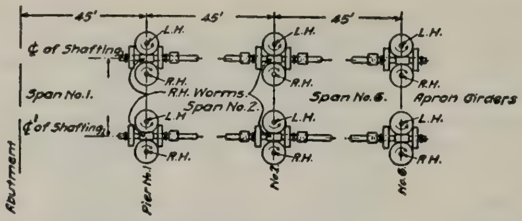


Fig. 28.—Operating Mechanism of Car-Ferry Landing; Texas & New Orleans.

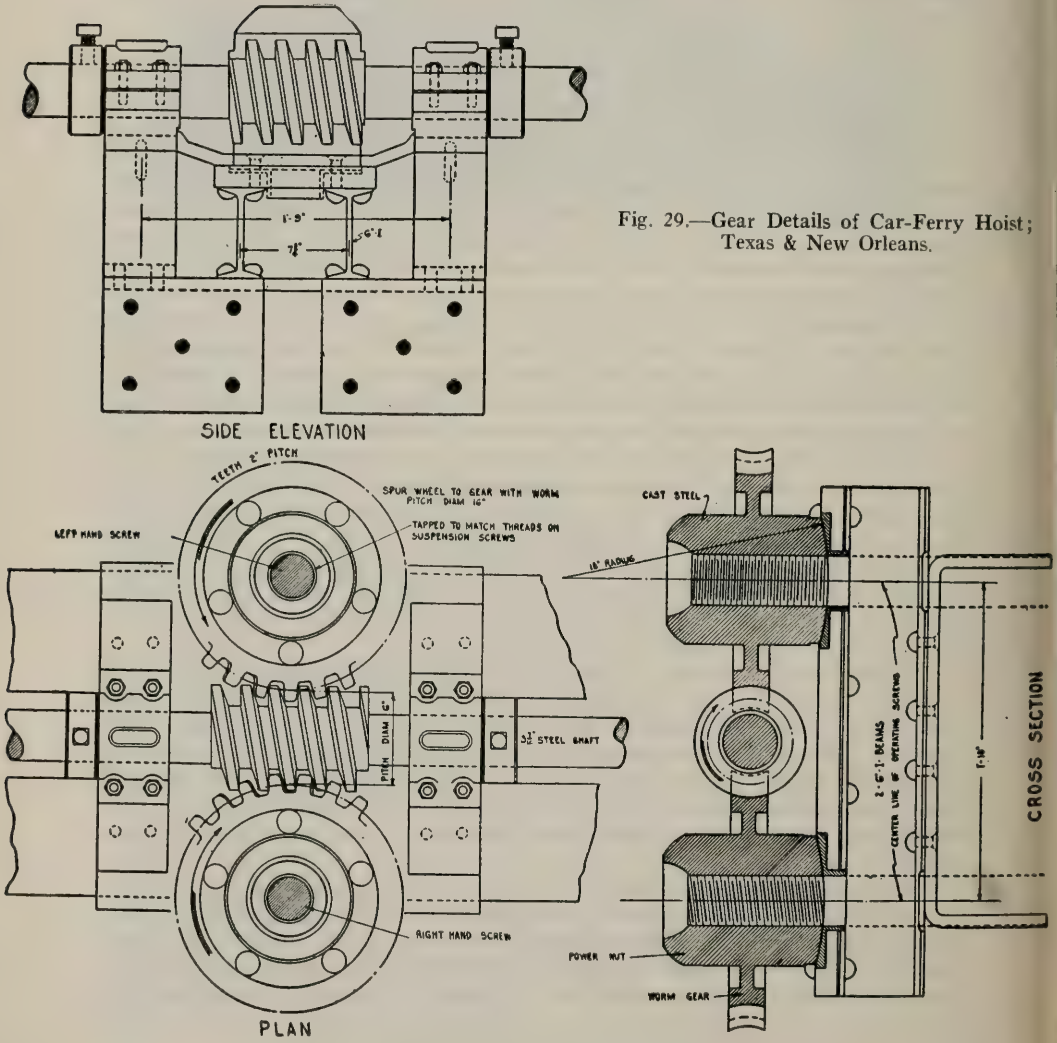


Fig. 29.—Gear Details of Car-Ferry Hoist; Texas & New Orleans.

The design of the screw-operated mechanism for the Chinese car-ferry landings is said to have been adapted from the plans of the New Orleans landing. But the Chinese landings have motors at each support, instead of a single motor with lines of shafting to the supports.

Texas & Pacific Railway.—For the New Orleans landing of the Mississippi River car-ferry of this road, which is still in service, there are six 50-ft. girder spans to form a continuous structure or deck. This structure has pin bearings at the shore end, and is suspended at the outboard end and five intermediate points by pairs of vertical hangers or suspension rods carried by overhead portal trusses or gallows frames. These rods are threaded in the upper part and are engaged by nuts carried on the transverse gallows frames. Longitudinal overhead beams carry the lines of shafting which drive the operating nuts, and these beams are supported at intermediate points by braces from the piers which carry the columns of the transverse gallows frames. The construction of the movable deck and its supports, and the arrangement of the operating mechanism, are shown in Fig. 30.

The threads of the operating screws vary at the several suspension points. In the original design, the pitch of the thread was ⅛-in. at the first support and increased ⅛-in. in each panel to ¾-in. pitch at the last or sixth support. Trouble with stripping of the ⅛-in. and ¼-in. threads was corrected by introducing internal gears, so as to slow down the line shafts near the shore end of the incline. This permitted the pitch to be increased to ⅜-in. and ¾-in. respectively, and since the change was made there has been no further trouble.

At support No. 4 is the motor house, with bevel-gear drive to two vertical shafts, which in turn have bevel-gear drive to two lines of shafting with worm-gear connections to the bronze operating nuts (or worm wheels). The shafting is carried on longitudinal beams which span between the supports or gallows frames.

For direct connection to the boat's deck, the outboard end of the incline is extended by a 25-ft. plate-girder apron, pivoted to the ends of the span girders. Near its outboard end, the apron rests on a transverse girder, about 35 ft. long, each end of which is suspended from the overhead structure by a chain attached to a threaded rod or operating screw. The nuts of these screws are operated by hand wheels, and by independent operation of the screws the apron can be tilted laterally to conform to a lateral list of the boat.

Alabama, Tennessee & Northern Railway.—A less elaborate multiple-span adjustment method has been applied by this road to a car-ferry at Mobile, Ala., serving an oil refinery on Blakeley Island by means of a double-track steel barge 200 ft. long and 35 ft. wide. Each landing consists of a 40-ft. girder span and a 30-ft. apron, with their adjacent ends framed against a cross girder seated upon a pontoon or buoyancy tank 8 ft. in diameter and 23 ft. 3 in. long. The distance is approximately one mile.

This floating tank adjusts the level of the two spans for a 6-ft. range of tide, the shore end of the 40 ft. span having convex bearing plates seated in concave shoes to permit of the vertical radial movement. The 30-ft. apron has its girders seated on brackets on the cross girder at the tank, and resting, at mid-length, on a transverse lifting girder composed of a pair of 15-in. I-beams 30 ft. long. To the ends of this girder are attached cables which pass over sheaves on timber towers and carry 7-ton counterweights. In this way, the outboard end of the apron can be adjusted to the level of the barge deck. Two 5-ton chain hoists are attached to the ends of the cross girder on the tank, and two 4-ton chain hoists to the ends of the lifting girder. These hoists are disconnected during transfer operations, or they would be broken by the weight of the cars. Any of the seagoing tugs at Mobile are used for handling the barge.

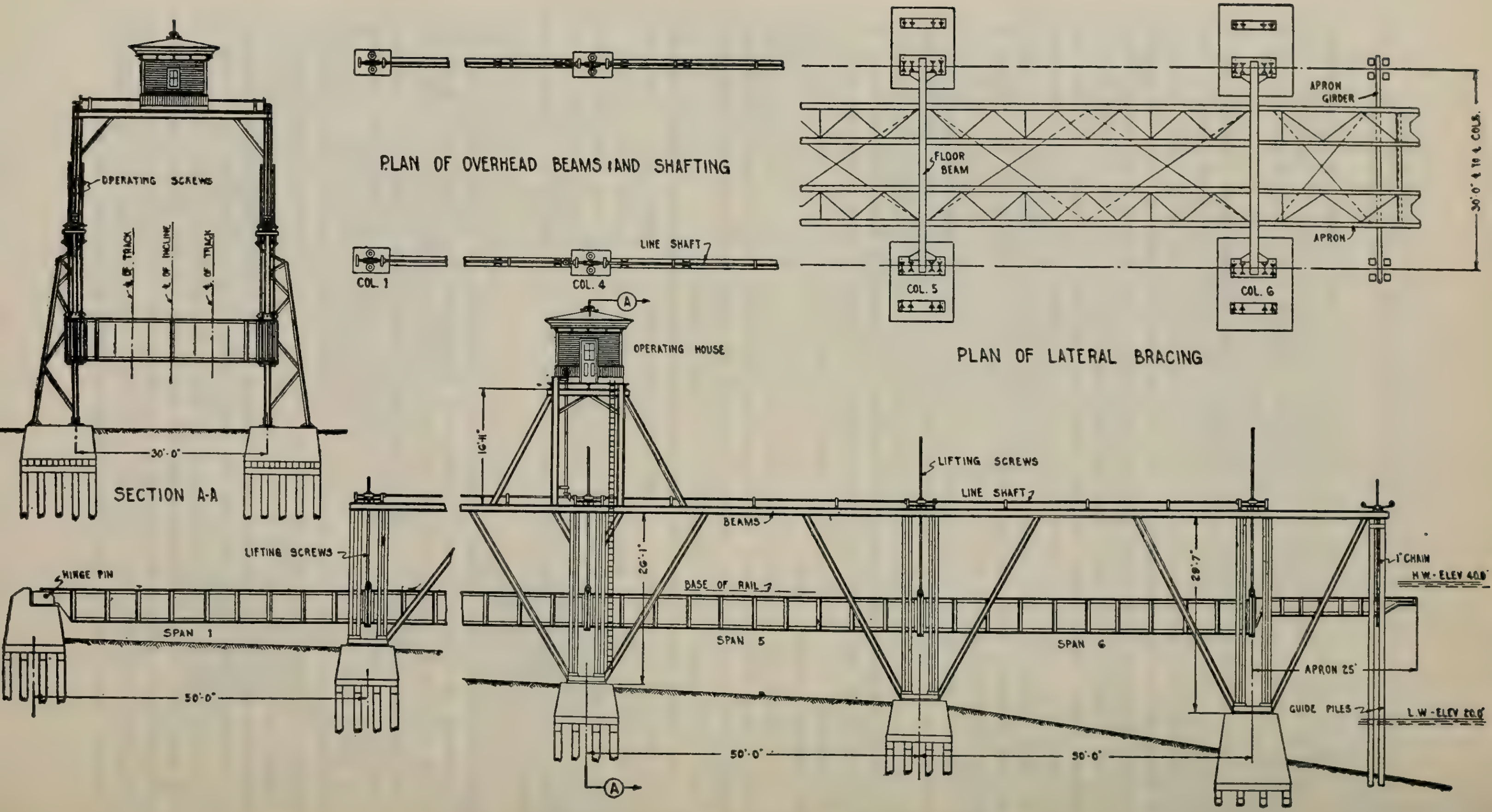


Fig. 30.—Car-Ferry Landing Bridge; Texas & Pacific Railway.

French State Railways.—At the terminal or landing of the Channel car-ferry at Dunkerque, France, connection between the tracks on the quay and those on the ship's deck is effected by a two-span through-truss bridge consisting of two 90-ft. spans, as shown in Fig. 31. To adjust the outboard end of this bridge to the varying level of the deck, the entire 180-ft. structure is raised or lowered as a unit, revolving upon a pivot bearing at the shore abutment. To permit of this operation, the structure is suspended from portal frames or trusses at the junction of the two spans and at the outboard end. Beneath the outer portal, each truss has attached to its top chord a sheave which lies in the bight or loop of a cable having one end anchored to the overhead truss. From the sheave, on the truss, the cable passes up and over another sheave overhead, beyond which its hanging end carries a counterweight. A separate cable with motor-driven hoist provides for the raising and lowering movements. Brackets on the ends of the bridge trusses ride in guides on the legs or towers of the portal.

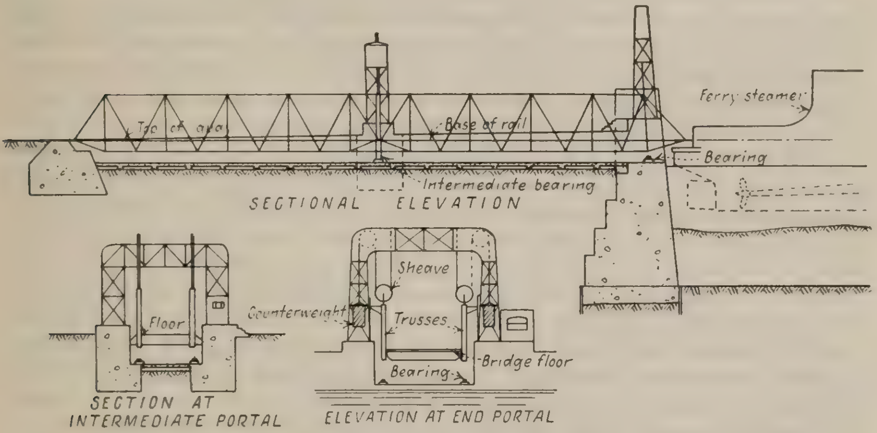


Fig. 31.—Car-Ferry Landing at Dunkerque, France.

The flexibility of the cable suspension permits the outboard end of the landing bridge to be tilted laterally to conform to the listing of the ship due to unequal loading as the cars are moved on and off the deck. At the intermediate portal, spanning the junction point of the two spans, the bridge trusses are held by vertical rods which pass through guides in the overhead truss and thus hold the spans in position during the vertical travel. The range of vertical travel at the outboard end is 12 ft. When this end is lowered to connect with the ship's tracks it rests upon the deck.

A single track on the first span diverges to two tracks on the outer span, to connect with the two tracks on the deck, so that the width at the end of the span is about 33 ft. Beneath the landing bridge is a concrete channel leading back from the dock or basin, and when the bridge is at its lowest position it rests upon bearings in this channel.

Traveling Cradle System

The adjustable apron span for connecting the shore with the car-ferry boat would be impracticable under certain conditions, as where a river with wide and flat banks has frequent and large variations in water level. For such conditions, a method developed on the Mississippi river is to lay an incline track diagonally down the bank, on a timber trestle, and on this to place a traveling platform or "cradle" having its deck on an ascending grade towards the river and carrying the approach tracks. The ascending grade reduces the necessary length of the cradle and checks cars against running away. The cradle is moved up and down the incline by a locomotive or hauling cable to maintain the river end of its deck level with the boat's deck. Lines of piling protect the incline and cradle, while clusters of piles form a landing slip for the boats. (See Fig. 11)

Illinois Central Railroad.—At the car-ferry at Trotter's Point, Miss., the incline has a descending grade of 3 percent. The cradle deck has an ascending grade beginning with 1 percent for about 30 ft., 2 percent for 35 ft., 3 percent for 140 ft. and then 1 percent for 28 ft. For the last 16 ft. the deck is horizontal and carries a 24-ft. hinged steel apron which projects about 8 ft. beyond the cradle for connection with the boat's deck. With a total length of about 250 ft., the height of the cradle ranges from practically nothing at the shore end, where the feather rails of its track slide on the incline rails, to 12 ft. from incline rail to cradle rail at the outer or river end.

This cradle consists of a heavy timber truss framework carried on 33-in. car wheels having axles 4 ft. apart. Near the shallow end, smaller wheels are used, and beyond them are sliding shoes. Feather rails for the track connection are steel forgings 15 ft. 3 in. long, grooved on the under side to slide on the incline rails. They are 9/16-in. thick at the upper end (with groove ⅛-in. deep) and 7½-in. deep where they are spliced to the cradle track rails. On each side of the forging is bolted a guide bar 8½ ft. long and depending down along the side of the head of the incline rail. Gage is maintained by ¾-in. tie-rods bolted through the rail webs and having 1-in. pipe sleeves as separators or spreaders. The apron is not counterweighted nor is it operated mechanically. The bow of the boat is simply run under the projecting end, the bow being so sloped as to engage the apron in this way. The cradles are shifted by a cable haulage system, the cable being pulled by a locomotive.

Texas & New Orleans.—A car-ferry landing of similar type at Avondale, La., was used for the crossing of the Mississippi river at New Orleans, until the opening of the Mississippi River bridge in 1935. The incline, with a descending grade of 3 percent, consisted of a three-track trestle having 15-ft. spans and 13-pile bents, except that for the submerged portion the spans were 10 ft. and the bents had 15 piles.

The cradle, 210 ft. long, was carried on 33-in. car-wheels, having the axles spaced about 7 ft. apart, but at the shallow end there were smaller wheels and finally sliding shoes riding on the incline rails. Its deck had an ascending grade of 2 percent for 71 ft., and then 3 percent to the outboard end. At that end, the height was 13 ft. from incline rail to cradle rail. The cradle was of heavy timber construction; 12 by 14-in. sills and chords; 10 by 12-in. truss posts and diagonals; 6 by 8-in. lateral struts and braces. All heavily bolted together and secured with 1-in. tie-rods.

At the outboard end of the cradle, the deck was dropped to admit the 24-ft. steel apron, which projected 8 ft. beyond the end of the cradle. Here, as at the Illinois Central Railroad landing, mentioned above, no machinery was used for adjusting the hinged apron to the level of the boat deck. A transverse timber supported it and limited its drop below the horizontal position. The face of the barge was formed with an inclined nose which would slide under the projecting end of the apron and raise it into proper

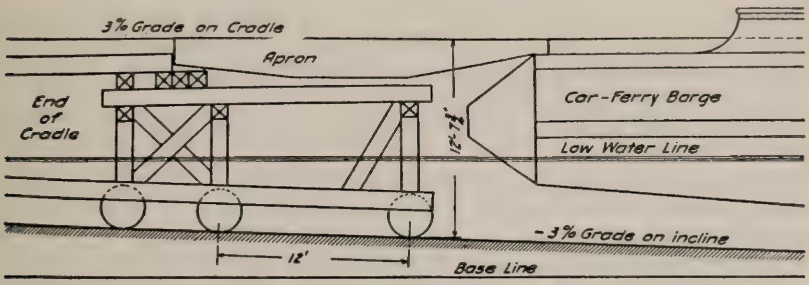


Fig. 32.—Landing Cradle for Car-Ferry; Texas & New Orleans.

position at the end of the car-deck. Shifting the cradle down the incline was effected by reaction of the retarding effect of brake application on a locomotive on the cradle. Shifting the cradle up the incline was accomplished by butting it with the barge. The steel apron on the cradle, and its connection with the barge, are shown in Fig. 32.

Missouri Pacific Railroad.—On the west landing of the car-ferry crossing the Mississippi river at St. Louis, the incline track, on a timber trestle of 10 ft. and 12 ft. spans, has a grade of 2½ to 4 percent. The cradle is 171 ft. long, or 209 ft. including its 38-ft. steel apron. Its deck and track are mainly on an ascending grade of 3 percent, and the apron is normally horizontal. At the shore end, cast-steel feather rails 24 ft. long slide on the incline rails. The cradle is carried on 33-in. cast-iron car wheels, with axles mainly 6 ft. 6 in. apart.

The steel plate-girder apron flares to an end width of 40 ft. to carry the turnouts connecting with the three tracks of the transfer boat. This end has V-shaped recesses engaging with corresponding projections formed at the end of the boat deck, so that the boat and apron are locked together against independent lateral movement. While the bow of the boat was so shaped as to slide under and engage the end of the apron, as in the cradles previously mentioned, the Missouri Pacific cradles had apparatus for adjusting the position of the apron. At each side of the cradle, near the outboard end, was a steel frame or bent mounted on a transverse beam and carrying a pair of sheaves for 1-in. cables having one end attached to the end of a floorbeam of the apron, and the other end carrying a counterweight. An additional cable was led up to a hydraulic jack mounted on top of the steel frame and operated by oil by means of a hand force-pump. By using the jacks independently, the apron could be tilted laterally to either side to conform to any list of the boat.

At the end of the cradle the apron girders are seated on an I-beam frame on a six-wheel steel truck attached to the timber frame. Each girder has a rocker bearing to allow for the radial movement, but has also a 44-in. pin to hold the girder in position. This pin is placed as near the top of the girder as practicable, in order to keep the gap between cradle and apron rails as small as possible. The pin hole is 4¼-in. in diameter, so that no vertical load can come upon the pin. These enlarged holes also provide for lateral swing of the apron, as the pile clusters which guide the boat into position cannot hold it in the exact center line of the cradle and incline.

This cradle system is used also at some Mississippi River ports to enable railway cars to be loaded and unloaded on the wharf boat, alongside the river steamers, although the cars are not taken on board. At Vicksburg, Miss., where the extreme variation of river level is nearly 63 ft., an incline track with a grade of 3½ percent was built diagonally down the bank, for about 1,100 ft., supported on a timber trestle. At the foot of the incline is the wharf boat or floating transit shed, which has two tracks extending along it. It is moored to pile clusters or dolphins about 60 ft. apart, parallel with the incline, each composed of 20 timber piles bound together with wire cables. The moorings are shifted with the changing stage of water level.

Connection between the incline track and the wharf boat is effected by a timber cradle, 117 ft. long, having a height of only about 2 in. at the land end and 9 ft. at the river end, so that its deck is practically level with that of the wharf boat. It is moved up and down the incline by a locomotive. A steel apron, 29 ft. long, is hinged to the outboard end of the cradle and seated on the deck of the wharf boat, to which it is connected by pins, thus making a flexible link between the cradle and the boat.

For a car-ferry crossing the Benue river, in Africa, steel cradles were installed by the Nigerian Eastern Railway in 1924. The incline had a track of 10 ft. 8 in. gage on a grade of 3.3 percent, and the cradle had an ascending grade of 3.3 percent for the deck, which was 14 ft. wide and carried railway tracks of 3 ft. 6 in. gage. Steel trusses 217 ft. long formed the frame of the cradle, which was mounted on steel wheels about 16 ft. apart. It had a solid steel deck, and this was widened to 22 ft. at the river end for turnouts to meet the five tracks on the boat. Cables and hand-operated winches moved the cradle on the incline as required by changes in water level.

Crane Transfer System

An entirely different and much more elaborate method of handling cars is used for the ocean-going American–Cuban and Atlantic–Gulf car-ferry services of the Seatrain Line. But in this case the ships carry about 100 cars on three or four decks, and the cars are raised and lowered through large deck hatchways, as already described. Furthermore, the trip is made only once a week. For such vessels the ordinary landing bridge is not applicable, and the special method of handling cars consists in the use of overhead cranes.

At the New Orleans terminal there is on the wharf or pier a steel tower crane carrying a traveling hoist or trolley, and having a 73-ft. cantilever extension which projects over the deck of the ship at about 60 ft. above the level of the pier. This extension is hinged, so as to be swung up out of the way as a ship comes alongside or moves away.

Each outbound car in turn is run onto an elevator platform in the crane tower. This platform is raised by the trolley hoist, which then runs out on the cantilever and lowers the platform to the desired deck. There the car is hauled off along the deck track by a cable and power capstan. Cars to be landed are hoisted out in the same way and lowered to the track on the pier. The platforms, about 44 ft. 6 in. long, form hatch covers during the voyage.

The crane tower is 57 by 35 ft. in plan, the narrower dimension (at right angles to the ship) accommodating two yard tracks, each with its lifting platform. For raising the platform there are two hoists, with tackle attached to each end. These hoists have motors of 250 hp. for a total lifting capacity of 105 tons, including the 15-ton car platform. A 40-hp. motor provides for raising the cantilever boom.

A somewhat different equipment is used at the New York port terminal. There, an overhead traveling crane spans the ferry slip and the two tracks which run along the side, the ship being moored with its car hatch directly under the crane runway. On the crane bridge are two electric hoists which raise the platform and car from the track, the crane bridge being then moved along the runway to bring its load directly over the deck hatch, through which the load is lowered to the desired deck level.

Appendix

Lake Constance Car-Ferry (page 1004).—Traffic at Romanshorn, Switzerland, has ranged from 50,000 to 85,000 cars per year. Only freight cars are handled. The time of crossing averages 50 min. to Friedrichshafen and 90 min. to Lindau. The two railway systems have their own boats, but these are all about 164 ft. long, having two tracks, and driven by twin screws with pairs of oil engines. The cars are moved on and off the boat at the stern, over a double-track landing bridge which has trunnion bearings at the shore end, while the outboard end is suspended from an overhead structure by counterweighted cables which provide for raising and lowering, as the water level varies considerably.

River Danube Car-Ferry (page 1005).—The distance between the ports is about 2½ miles and will be covered in 30 to 45 min. The two boats will be 215 ft. long, with three tracks, and will carry through sleeping cars as well as 15 freight cars of 30 tons capacity. The Roumanian boat, built in Germany, has twin screws of the Voith-Schneider type, driven by oil engines. For a 25-ft. range of level in the river, the Roumanian landing has an adjustable landing bridge 656 ft. long, with 6 spans.

English–Belgian Motor-Car Ferry (page 995).—The special vessel for the Dover–Ostend service, provided through the Belgian Ministry of Marine, which was put in service in 1936, has a capacity for 110 automobiles and some 300 passengers. The voyage is 62 miles and is made in about 3½ hours. The boat is 300 ft. long and 36 ft. beam, with a loaded draft of 10 ft. 6 in. Although there is a tidal range of about 20 ft., no expensive landing equipment is required, owing to the curious alternative of building the ship with three decks, either one being used according to the level of the water. Simple ramps on the ship, operated by electric hoists, connect the quay with the deck that is approximately level with it, each ramp accommodating a difference of 6 ft. Fixed ramps connect the different decks. Three screws, with engines aggregating 9,000 hp., give a sea speed of 20 miles per hour. The boilers are fired with oil fuel.

Turkey.—For the Bosporus car-ferry, already noted, the distance is 2½ miles and the actual time of crossing is estimated at 13 min. But in addition there would be 4 min. for leaving one side, 8 min. for entering at the opposite side, and 50 min. for unloading and loading after the boat is moored, so that each crossing would take about 1¼ hours. The ferry-boat, 300 ft. long, will have 3 tracks, giving a total usable length of 656 ft., accommodating 7 sleeping-cars or 20 freight cars of 30 tons total weight. The variation in water level is only about 27 in.

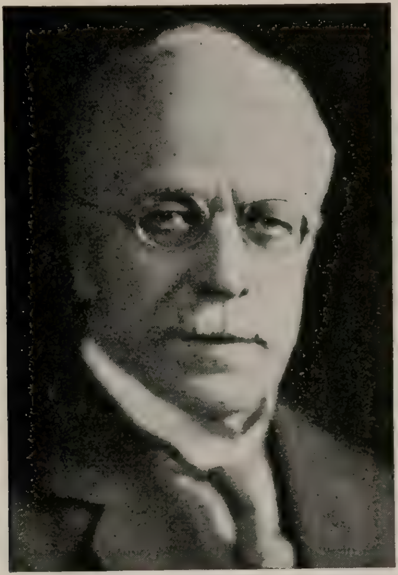
Note.—Bibliographic notes relative to published articles dealing with Car-Ferries will be found in the bibliographies of published railway information which accompany the annual reports of the Yards and Terminals Committee of the American Railway Engineering Association.

Memoir

William Channing Cushing

Died January 11, 1940

William Channing Cushing was descended from an old New England family—through a Cushing who came to Hingham, Mass., in 1638, he derived membership in the New England Society of Pennsylvania. He was born in St. John, New Brunswick, on March 18, 1863, the child of United States citizens. He married Miss Marie Bacon Dye of Indianapolis, Ind., on February 14, 1894.



William Channing Cushing

He was educated in the public schools of St. John, N. B., and at the University of New Brunswick in Fredericton, from which he was graduated in 1884 with the degree of B. A. In the Autumn of 1884 he entered Massachusetts Institute of Technology as a member of the second year class, and was graduated from that school in 1887 with the degree of B. Sc. in the Department of Civil Engineering. In the course of his undergraduate career at the University of New Brunswick he was awarded "Honors in Classics", 1881–1882; "Honors in English", 1882–1883; and "Honors in French", 1883–1884. Later, the university conferred upon him the degrees of M. A. (in 1886), and LL. D. (in 1922).

Immediately after graduation from Massachusetts Institute of Technology, Mr. Cushing was appointed assistant engineer to Mr. George W. Kittredge, division engineer, Louisville division of the Pennsylvania Lines West of Pittsburgh, and he continued in the service of the Pennsylvania until the date of his retirement in 1933, holding successively the following positions:

June, 1887–January, 1889—rodman, Louisville division
January, 1889–July, 1890—engineer maintenance of way, Jamesville branch of the Cincinnati division
August, 1890–May, 1894—division engineer, Columbus division
June, 1894–December, 1900—division engineer, Panhandle division
January, 1901–December, 1901—superintendent, Panhandle division
January, 1902–December, 1902—superintendent, Eastern division
January, 1903–June, 1918—chief engineer maintenance of way, Southern system
June, 1918–February, 1920—chief engineer maintenance of way, Pennsylvania Lines West of Pittsburgh
March, 1920 to 1933—engineer of standards, staff of chief engineer, Pennsylvania Railroad System

However, his activities and interests were by no means confined within the strict limits of railroad engineering. He was a delegate, representing the Pennsylvania Railroad, at the International Railway Congress held in Washington, D. C., in 1905 and at Berne, Switzerland, in 1910. He was named a reporter for North and South America by the Permanent Railway Commission and prepared a report on special steels for the session which was to have been held in 1915, but later abandoned because of the war. When the sessions were resumed, he was again commissioned reporter on the same subject for the ninth session held at Rome in 1922. At the tenth session, held at London in June, 1925, Mr. Cushing was commissioned a reporter for all of America on the question of breaking of rails and joints.

Mr. Cushing became identified with the American Railway Engineering Association in 1900 as charter member No. 16, and served the Association with distinction, being elected president for the term from March, 1911, to March, 1912, and being advanced to honorary membership in 1929. He also served the Association in the following capacities:

Member—Committee on Ties—1900–1901
Vice-Chairman—Committee on Ties—1902
Vice-Chairman—Committee on Signals and Interlocking—1903, 1904, 1905
Member—Special Committee on Classification of Track—1905, 1906, 1907
Member—Committee on Rail—1909–1912, inclusive; 1916–1932, inclusive
Chairman—Committee on Rail—1913
Vice-Chairman—Committee on Rail—1914, 1915
Member—Special Committee on Stresses in Railroad Track—1914–1940
Member — Committee on Cooperative Relations with Universities — 1924–1933, inclusive
Chairman—Committee on Standardization—1927–1931, inclusive

He was a life member of the American Society of Civil Engineers, having joined in 1889. He was a member of the British Institute of Civil Engineers, and of the Societe des Ingenieurs Civils de France; a member of the American Society for Testing Materials, and at the time of his death, one of the Honorary members of that organization. He was a member of the American Engineering Standards Committee (now American Standards Association), the Engineers' Club of Philadelphia, the Franklin Institute, and the Veteran Employees' Association of the Pennsylvania Railroad Company.

Mr. Cushing joined the Franklin Institute in 1931 and was made a member of the Committee on Science and the Arts on February 17, 1932, rendering most valuable service on many important subcommittees. As a member of the Committee on Science and the Arts, he brought to bear with all his activities, a thoroughness, technical knowledge, and kindly forcefulness that rendered his connection of the highest value.

A gentleman of polished manners, he was extremely modest and unassuming. Faithful and conscientious in the performance of all his duties, he invariably maintained a very high professional standard.

His published studies are as follows:

1. Method of Procedure in Remodeling Yards; Railroad Gazette, January 4, 1901
2. A New Yard Design; Railroad Gazette, March 13, 1903
3. Progress in Yard Design; Railroad Gazette, May 12, 1905, and AREA Proceedings, Volumes 7 and 9
4. English Translation of "Etude sur les Deformations de Voies de Chemins de Fer et les Moyens d'y Remedier"; Railroad Gazette
5. The Life of Steel Ties; Railroad Gazette, June 5, 1908
6. The Question of Screw Fastenings to Secure Rails to Ties; AREA, Volume 10–2, 1909
7. Track Superstructure of German Railways; AREA, Volume 11–2, 1910
8. Protecting and Waterproofing Solid Floor Bridges; AREA, Volume 12–1, 1911
9. A Study of Forty Failed Rails; AREA, Volume 12–2, 1911
10. The Question of the Improvement of Rail Design and Specifications from 1893 to the Present Time; AREA, Volume 13, 1912
11. Some of the Causes of Rail Failures; AREA, Volume 17, 1916, and Minutes of Proceedings of the Institution of Civil Engineers, London; Volume CCI, 1915–1916, Part 1 (Awarded "Manby Premium")
12. Examination of Rails Long in Service for Relation Between Internal Stresses and Strains and Transverse Fissures; AREA, Volume 21, 1920
13. Special Steels; AREA, Volume 17, 1916, and International Railway Congress Association, Ninth Congress, Rome, 1922
14. On the Question of Breaking of Rails; Joints (Subject 11 for discussion at the tenth session of the International Railway Congress), Bulletin of the International Railway Congress Association, Volume VI—No. 10, October, 1924

This memoir is dedicated to the honor of this capable and esteemed member of the American Railway Engineering Association, and as a record of a great loss which the engineering profession has sustained.

A. R. Wilson, *Chairman*
F. M. Graham
G. W. Kittredge
Committee on Memoir.

Memoir

James Clark Irwin

Died March 20, 1940

James Clark Irwin was born on September 23, 1868, at Cheyney, Delaware County, Pa., the son of William Henry and Catherine (Browning) Irwin. He attended the Protestant Episcopal Academy at Philadelphia and was graduated from the University of Pennsylvania in 1890 with the degree of Bachelor of Science and, in 1891, received the degree of Civil Engineer from the same university.

He married Frances Smith Monaghan of Westchester, Pa., on June 5, 1895. They had four sons, James C., Robert M., William H., and John, and one daughter, Katharine. James, Robert, John and Katharine, together with Mrs. Irwin, survive him.

James Clark Irwin

While attending the university, he was employed during summer vacations on various engineering projects and, upon his graduation, was an instructor in civil engineering at the university for about a year.

On July 1, 1892, Mr. Irwin entered the service of the New York Central & Hudson River Railroad in charge of construction of the block signaling system between Buffalo, N. Y., and Albany and was continually in the employ of the New York Central System from that time until his retirement on October 1, 1938.

In 1893 and 1894, he was assistant trainmaster of the Mohawk division; from 1894 to 1898, assistant superintendent of signals, and superintendent of the Hudson River Bridge Company; from 1898 to 1902, division engineer of the Mohawk division (Albany to Syracuse and Utica to Malone); in 1902, he was appointed signal engineer and, later, assistant to general superintendent, making studies for relief of congested terminals. In 1903, he was superintendent of the Lake Erie, Alliance & Wheeling Railroad; from 1903 to 1906, he was engineering assistant on the staff of the vice-president, making studies for grade revision, terminal improvements, and electrification of lines. From 1906 to 1908, he was resident engineer and superintendent of construction on the Grand Central terminal improvements; in 1908, he became office engineer in charge of contracts; from 1909 to 1912, he was chief engineer of the Rutland Railroad; and from 1912 until his retirement in 1938, he was with the Boston & Albany Railroad—becoming valuation engineer on May 1, 1920.

On April 4, 1893, Mr. Irwin was elected a junior of the American Society of Civil Engineers, transferring to the grade of associate member on December 7, 1898, and was elected a member in 1900. He was a familiar figure, particularly at the annual meetings of the society held in January in the City of New York each year, and had a wide circle of friends among the membership of the society. In 1904, he had charge of the installation of the exhibit of the society at the St. Louis Exposition.

Mr. Irwin was one of the pioneers in modern railroad signaling. He was one of the charter members of the Railway Signaling Club, predecessor of the Railway Signal Association—now the Signal Section, Engineering Division, of the Association of American Railroads. He enrolled on September 14, 1897, and was made a life member on December 15, 1938. He took an active interest in the affairs of the association during his entire professional career.

On May 29, 1907, Mr. Irwin was elected to membership in the American Railway Engineering and Maintenance of Way Association, now the American Railway Engineering Association, and became extremely active in its affairs—serving on the following Committees:

Committee 20—Uniform General Contract Forms—1909 until his death
    Vice-Chairman—1910–1913, inclusive; 1923–1926, inclusive
    Chairman—1927–1931, inclusive.

Committee 26—Standardization—1927–1930
    Chairman—1931–1935, inclusive

Committee 12—Rules and Organization
    Vice-Chairman—1939 until his death

He also served as director from March, 1932, to March, 1935; vice-president from March, 1935, to March, 1937, and president in 1937–1938. Upon his election to the presidency of the American Railway Engineering Association in 1937, Mr. Irwin became chairman of the Engineering Division, AAR, and during his administraton, he was deeply interested in and furthered the cause of research in engineering matters for the AAR. He was instrumental in the appointment of the Joint Committee on Relation Between Track and Rolling Stock.

Mr. Irwin's interest in the work of the American Standards Association began in 1930 when he became a member of the ASA Standards Council representing the Engineering Division of the AAR. He was elected chairman of the Standards Council in 1933 for the three years ending with 1936, and in this capacity he served also as a member of the Board of Directors for 1934–35–36 and as ex-officio member of the Board for 1937–38–39, as well as ex-officio, of the Council.

In promoting an understanding of ASA work within his own group, and in encouraging the correlation of AAR standardization activities with those of other industries through ASA procedure, Mr. Irwin rendered valuable service. His unusual ability, and the thoroughness with which he carried through an undertaking, coupled with his enthusiasm for the task, qualified him well for his service in such a great number of different phases of ASA work.

Although Mr. Irwin's professional activities were so extensive, he found time to take part in many social, religious, and civic activities. He was, at various times:

Member of the New England Railroad Club, serving on its executive committee and as president
Member of the New York Railroad Club
Member of the Railway Guild (railway honorary society)
Life Member of The Episcopal Academy Alumni Society
Member of The General Alumni Society, University of Pennsylvania, also serving as a member of the board and as vice-president
Member of the Associated Pennsylvania Clubs, serving as president
Member of the New England Alumni Society of the University of Pennsylvania, serving as president
Member of the Committee on Annual Giving of the University of Pennsylvania
Member of Academy of Political Science
Member of National Security League
Governor of The University Club—Boston
Member of The Episcopalian Club of Massachusetts, serving also as a member of its council, as chairman of its Membership committee, and as president (1933)
Scoutmaster, troop committeeman, district commissioner, president of council (Norumbega—Newton, Needham and Wellesley, Mass.) and as a member of Greater Boston Council, Boy Scouts of America—serving from 1913 to 1933

For 15 years, he was either vestryman, junior warden or senior warden of St. John's Church, Newtonville, Mass.

In 1916 and 1917, he was chairman of the New England Committee on the Study of Military Mobilization and a member of the Business and Professional Men's Military Battalion, under the direction of the First Corps Cadets, Boston.

From 1917 to 1920, he was Chairman of "Troop C Home Folks" and "Home Association of the 102nd Machine Gun Battalion, 26th Division". (Three sons served in the World War.)

In 1918, he was appointed by Governor McCall as a delegate from Massachusetts to the "Win the War" convention in Philadelphia.

He was active in and once president of the Newtonville Improvement Association and a member of the Zoning committee, City of Newton, for Newtonville.

James C. Irwin loved his home and was devoted to his family. His was a typical American home, a truly Christian one, and he took real pleasure in entertaining his friends in that atmosphere. Those whose good fortune it was to meet him and to know him, whether in his home or in a professional or social way, were all impressed with his worthwhile character, his high moral standards of living, his earnestness, his sincerity, his ability, and his kindly consideration of all. Nothing was too hard or difficult for him to do for any friend, and any work he undertook was given his most scrupulous attention. The following quotation from Pope describes the manner of man those who knew him found him to be:

> But where's the man who counsel can bestow,
> Still pleased to teach, and yet not proud to know?
> Unbiass'd, or by favor, or by spite;
> Not dully prepossessed, nor blindly right;
> Though learn'd, well-bred; and, though well-bred, sincere;
> Modestly bold and humanly severe;
> Who to a friend his faults can freely show;
> And gladly praise the merits of a foe;
> Blest with a taste exact yet unconfined;
> A knowledge both of books and human kind;
> Generous converse, a soul exempt from pride;
> And love to praise, with reason on his side?

Our Association, the railroad world, his friends and his community have lost in the passing of James Clark Irwin an exemplary citizen, a cultured Christian gentleman, the like of whom makes the world a better place for his having been in it, and one who leaves behind him the respect, the love and admiration of his multitude of friends.

He gave generously of his time and talents
and with rare ability and good judgment promoted the welfare
and enhanced the work and prestige of this Association.

W. F. Cummings, *Chairman*
W. T. Dorrance
W. D. Faucette
E. M. Hastings
F. L. Nicholson
W. G. Nusz
A. R. Wilson
Committee on Memoir.

Memoir

August Ferdinand Blaess

Died February 19, 1940

August Ferdinand Blaess, the son of Albert F. and Catherine (Guenther) Blaess, was born on a farm near Saline, about six miles south of Ann Arbor, Mich., January 6, 1871. His earliest educational training was that provided for the youth of rural communities in the eighties of the last century. Such training was supplemented by a sterner and more practical one that comes to a farm lad who at an early age was observing, methodical, deliberate and unwilling to announce a conclusion unless warranted by the known facts. He accepted the conditions of his early youth with filial compliance and looked forward expectantly to his majority when he could begin technical training in preparation for the engineering profession.

August Ferdinand Blaess

The University of Michigan nearby presented the facilities he sought. He knew that the completion of a four year course in civil engineering at the university was contingent upon retaining his residence on the farm when as time would permit he could assist in the farm operations. Although he knew that such an arrangement would require daily commuting in a two-wheeled buckboard, would entail many sacrifices and would deprive him of many of the pleasures of university life others enjoyed, he enthusiastically undertook the task and graduated in June 1895 with the degree of Bachelor of Science in Engineering. In his mature years he expressed the opinion that the method circumstances forced him to adopt to acquire his engineering training was an admirable one notwithstanding its disadvantages. The daily trips between his home and the university and the routine of farm obligations forced him to budget his time, a characteristic of procedure that clung to him throughout his career. An abstruse problem in descriptive geometry became clear to him on one of his trips as he studied the conformation of the water contour of an irregular knoll in a nearby flooded field.

Of the many classes of civil engineering at the time of his graduation, that pertaining to the location, construction, maintenance and operation of railways had the greatest appeal to Mr. Blaess. At that time the railways were at the threshold of a program of building multiple main tracks and extensions into unoccupied territory, making revisions of alinement and gradients to secure greater operating economies, creating extensive terminals and working out grade separations in congested centers. There seemed to be a greater opportunity for the young engineer with the railways and accordingly he determined to make railway engineering his life work, if a position on a railway could be obtained during a serious depression.

In nearly 43 years of almost continuous railway service, Mr. Blaess was employed by two railroad companies. From July, 1895, to July, 1896, he was employed as assistant engineer on preliminary surveys, location and construction on the Detroit & Mackinac Railroad. After a period of a few months he entered the service of the Illinois Central Railroad as track apprentice. The work as track apprentice was exactly what the name implies. The tasks of laying, ballasting and surfacing tracks, ditching and other similar work, with brief respites now and then to set line and ballast stakes were accepted as the day's work by the young engineer. He was transferred to construction engineering work in 1897 and worked as rodman, instrumentman and resident engineer on second-track work and the St. Charles Air Line elevation, the first work of its kind in Chicago. In 1901 he was transferred to the maintenance department as assistant engineer. There followed successive promotions: May 1, 1902, supervisor Cherokee division; March 27, 1905, roadmaster Springfield and Louisville divisions; December 15, 1910, assistant engineer maintenance of way of the system; August 25, 1913, district engineer at Memphis and Chicago; April 1, 1914, engineer of maintenance of way, system; and February 1, 1925, chief engineer, system, in which position he continued until his retirement May 1, 1938.

At the time of Mr. Blaess' entry in the service of the Illinois Central Railroad the system road mileage was 3,935 and at the time of his retirement it was 6,614. His work contributed materially to the growth in mileage as well as constructing heavier track, bridges for greater loadings, and extension of terminal facilities. Among the many projects carried out under his supervision may be mentioned a gravity classification yard known as Markham, Ill., together with a modern mechanical plant on the south side of the Illinois Central Chicago terminal; grade separation from 111th Street, Chicago, 30 miles south; a low grade line from Odin, Ill., south to connect with the Metropolis bridge near Paducah, Ky.; system locomotive and freight car repair shop at Paducah, Ky.; and the construction of 1¼-mile bridges for both the I.C. and Y.&M.V. to span the Bonnet Carre spillway discharge of 250,000 second-feet from the Mississippi river in southern Louisiana. His four years' training at the University of Michigan was exemplified in many ways during his 41 years of service with the Illinois Central. No problem was too intricate for him to master. He displayed that thoroughness, patience and regard for opinions of superiors and subordinates he acquired during the four university years when he was preparing for his life's work.

He was admitted to membership in the American Railway Engineering Association March 15, 1906. The work in the association was along the line of his chosen profession and he enthusiastically accepted assignments to committee service and worked for the Association in the same manner as for his railway employer. During his years of membership he served on the Track committee, Roadway committee, Economics of Railway Labor committee, Waterways and Harbor committee, Rail committee, and was vice-chairman of the Rail committee 1929–1938. He was a member of the unit from the Rail committee which cooperated with the Rail Manufacturers Technical committee on Investigation of Failures of Railroad Steel Rails. He was director of the Association 1924, 1925 and 1926, and treasurer 1930 to 1938.

He was elected a member of the Western Society of Engineers in 1926 and of the Chicago Engineers Club in 1922. He was a Mason and a member of the South Shore Country Club.

Throughout his career he met the many problems of life, great and small, under all kinds of conditions and circumstances, with patience, an understanding of men and methods, and an ability and vision to plan and execute. He was an excellent example of that type of an engineer and a gentleman which the profession delights to honor.

F. E. Morrow, *Chairman*
D. J. Brumley
Robert H. Ford
Committee on Memoir.

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